PB-217 912

WASTE WATER RECLAMATION VIA ARTIFICIAL RECHARGE AT RIVERHEAD, NEW YORK

John J. Baffa
New York, New York

1 May 1968

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PB 217 912

REPORT
TO
NEW YORK STATE DEPARTMENT OF HEALTH
AND
SUFFOLK COUNTY DEPARTMENT OF HEALTH
UPON
WASTE WATER RECLAMATION
VIA ARTIFICIAL RECHARGE
AT
RIVERHEAD, N. Y.

(WPD 82-02-66)

INTERIM STUDIES
PROGRESS REPORT NO. 3

JANUARY 1967 TO DECEMBER 1967

JOHN J. BAFFA, CONSULTING ENGINEERS
THE LAUMAN COMPANY, WELL DRILLING
LAUMAN LABS, INC. FIELD LABORATORY

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May 1, 1968

LETTER OF TRANSMITTAL

New York State Department of Health
84 Holland Avenue
Albany, New York 12208

Re: Riverhead Research Project

Attn: Dr. Leo J. Hetling
Director of Research

Dear Dr. Hetling:

Attached hereto is one copy of Progress Report No. 3, representing interim studies during the year 1967 while awaiting delivery and installation of instrumentation, degasifier, diatomaceous earth filter and new injection well.

The results of these studies have been applied to the design of the new injection well.

I wish to express my appreciation for the continuing dedication of the project staff, all of whom have contributed to the progress of this work.

Very truly yours,

John J. Baffa

John J. Baffa,
Consulting Engineer

HOLLIS S. INGRAHAM, M.D. COMMISSIONER OF HEALTH

RIVERHEAD RESEARCH PROJECT

PROJECT STAFF

NEW YORK STATE DEPARTMENT OF HEALTH

DONALD B. STEVENS, P.E.,
FORMER DIRECTOR OF RESEARCH

KENNETH STEVENS
FORMER ASSISTANT DIRECTOR OF RESEARCH

DR. LEO J. HETLING
CURRENT DIRECTOR OF RESEARCH

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SENIOR ENGINEER

RICHARD LAUMAN
SUPERINTENDENT

LAUMAN LABORATORIES, INC. - FIELD LABORATORY

BARRY D. ANDRES
DIRECTOR

JOHN PEDNEAULT
CHEMIST

RIVERHEAD RESEARCH PROJECT

SUMMARY STATEMENT

Research was continued during the year 1967 on studies of factors affecting infiltrative capacity of the soil water interface and percolative capacity of the soil with respect to the transport of single stage trickling filter effluent, which has received filtration through anthracite media. The facilities available also afford a means of studying the capability of the soil mantle of the earth to treat waste water. The character of the intermediate type effluent available at Riverhead provides a means of accelerating the occurrence of the effects of recharging organic materials contained in waste water effluent.

The relatively high organic content available in the effluent provides an immediate accumulation of organics which would otherwise require many months if the available effluent were more fully oxidized.

It was found that the infiltrative capacity of the soil interface progressively deteriorates and cannot be restored to full efficiency by simple pumping or surging. Accordingly, the new injection well has been designed to enable renewal of the interface material.

It was found that percolative capacity is affected as far as 40 feet from the injection point; is affected in greater degree closer to the injection point; and the distance, from the injection point within which permeability is affected, increases with length of time that injection water is applied.

It was found that the application of waste water containing organic matter introduces organic material in the pores of the soil which adheres to the sand grains and has the effect of introducing a greater number of fines and creating a more uniform aquifer material. This material which remains in the aquifer contains nitrates, nitrite, ammonia, sulfates, iron, phosphates, MBAS and volatile solids. Nitrates, phosphates and sulfates are retained in greatest degree. These materials are in maximum concentrations in the soil near the injection interface with lesser concentrations as distance from the injection well increases. Coliform bacteria are also introduced into the soil by the recharge of filtered sewage effluent in spite of heavy chlorination. Resting periods of the aquifer between sewage injections exhibited definite trends in some ground water constituents, particularly total nitrogen and sulfates which increased dramatically during resting periods between injection.

Thus, the portion of the soil mantle in use, represents a biological contact bed receiving an oxygenated influent via the injection well interface and produces organic and inorganic residues which remain in the soil interstices and cause changes in the biological and chemical characteristics of the percolating water. The percolative capacity of the aquifer is thereby affected.

The work to date indicates that secondary and/or tertiary treatment by biological means would be most advantageous in reducing organic content of recharge effluent as compared with intermediate type treatment. Reduction of organic content has the three fold advantage of decreasing maintenance of the infiltrative interface, lessening the effect on percolative capacity and reducing mineral addition to the ground water, by reason of lessening the amount of organic material which cycles through oxidation - reduction phases such as nitrogeneous, and sulfur bearing compounds.

It has been repeatedly indicated in this work that heavy chlorination of the applied recharge water increases turbidity which affects infiltration and percolation and also produces chlorides which represent an undesirable addition to ground water.

The continuation of research during the year 1967 included the following:

a. Redevelopment of the ground well and injection of filtered sewage effluent until it clogged.

b. Anothex repetition of this procedure.

c. Coincident injection into the simulator well and subsequent analysis of contents of simulator sampling tubes.

d. Emptying of simulator and analysis of its aquifer material contents after several years of use.

e. Constant head application of filtered sewage effluent to a simulator sampling tube with coincident measurements of flow, organic material and performance and subsequent analysis of aquifer contents.

f. Continued observation of ground wells with hydraulic and quantity measurements and studies, permeability and quality effects due to ground water travel.

g. Continued observation of long term operation of rapid filter employing anthracite media for filtration of single stage intermediate treatment trickling filter effluent.

Interim Studies were continued at the Riverhead project after the completion of the filtered sewage effluent injection stage, which was terminated in December 1966 and which was described in Progress Report No. 2. The interim studies were accomplished during the period of waiting for equipment deliveries for the diatomite filter, degasifier and instrumentation installation.

REPEATED INJECTION AND REDEVELOPMENT OF GROUND WELL

After the injection well clogged in December 1966, attempts at redevelopment by pumping alone failed. It was found necessary to use a surge block with alternate surging and pumping for a few days. When it was possible to pump 40 gpm from the well for a few hours, the redevelopment was considered complete.

Injection of filtered trickling filter effluent was begun on July 19, 1967 at 20 gpm and was continued until the well clogged 35 days later. As may be seen from Plate A, the clogging rate was 0.9 feet per day for the first twenty days and then flattened out to almost one third of this value for another fifteen days when clogging occurred.

The well was again redeveloped by surging and pumping and injection was again begun on September 29, 1967 at 20 gpm. This time the well clogged in thirteen days at an average rate of 0.9 feet per day as shown on Plate B.

On Plate C the clogging rates as measured by water level rise inside the well casing are compared for fresh water injection and all of the filtered effluent injections to date.

Cumulative clogging of the infiltrative surface is indicated by a higher level being reached sooner during each successive injection.

The average long term filter performance for June to September 1967 is shown on Plate D. During the entire period, 18 to 20 ppm of chlorine were added to the filter influent, representing breakpoint chlorination to a true residual. The bacteria and BOD removals by the filter are in large measure due to chlorination as is the large increase in chloride content. The filter effluent applied to the well had the following average constituents:

BOD	27 ppm	Range 0-183 ppm
COD	122	Range 68-234
Suspended Solids	65	Range 28-94
Volatile Suspended Solids	47	Range 19-73
Volatile Total Solids	180	Range 148-281
MBAS	2.3	Range 1.2-4.2
Chlorine Residual	0.86	Range 0-1.5

EXAMINATION OF INFILTRATIVE INTERFACE

Coincident with injection into the ground well, filtered sewage effluent was injected into the simulator well and the infiltrative interface in the simulator sampling tubes was examined.

Sieve analysis of the tube contents is shown on Plate 3-7. The face of the gravel pack contained much more fines after recharge for five days. Plate 3-8 shows results for the July 1967 injection test and Plate 3-9 for the August 1967 test. For the August test only iron and sulfate were determined. Ammonia, Nitrite, Nitrate, Phosphate, sulfate and iron were in greatest concentration in the aquifer material at the aquifer-gravel pack interface. Nitrate had the highest concentration and next in order were phosphate and sulfate. Organic content as measured by the volatile solids test was highest at the gravel pack interface at the well casing.

The concentration of iron and sulfate increased to a higher level in the August test above that obtaining in the July test, indicating a cumulative effect.

The nitrogen cycle was studied by converting Nitrate, Nitrite and Ammonia to equivalent Nitrogen and plotting the concentration retained in the simulator sampling tube aquifer material after 5 days injection as shown in Plate 3-10. The concentration of total nitrogen retained in the aquifer material reaches a peak at 12 inches from the face of the injection well.

INFILTRATIVE CAPACITY STUDIED BY CONSTANT HEAD TEST

One of the simulator tubes was packed with aquifer material and filtered sewage effluent was allowed to flow through it under submerged conditions under an applied pressure of 23 feet of water. The application was made through the simulator injection well as a recharge operation. The applied head was kept constant and the flow allowed to vary. The applied water was chlorinated to a free chlorine residual.

The flow started at 1 GPM per square foot and in 9 days reached 0.19 gpm per square foot. In 35 days it had receded to 0.03 gpm per square foot. A plot of the flow curve is shown on Plate 3-28. The flow is plotted cumulatively on Plate 3-29. Sixty percent of the total flow had passed through the tube in 9 days or almost 25 percent of the time.

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Total organic carbon determinations were made as shown on Plate 3-28 for tube influent and effluent. The data show alternating periods of TOC removal and TOC increase. At the beginning of the period, the TOC passing a 0.22 μ filter was removed while that passing a 5 μ filter showed an increase.

After the 37th day of application, the flow dropped to 0.01 gpm per square foot. At this time, sieve analyses were made of the gravel pack and aquifer material as shown on Plate 3-30. The analyses were made for every one inch layer of gravel pack. As a result of the recharge application, the first four inches of gravel pack particles contained a greater percentage of large particles than originally and the fifth and sixth inches of gravel pack contained more fines than before recharge.

The sample tube contents at various distances from the face of the injection well were analyzed for:

Nitrate
Nitrite
Ammonia
COD
Total Volatile Solids
Phosphate
Iron
Sulfate
MBAS
Alkalinity
Chloride

The results are plotted as percentages of average on Plates 3-31 and 3-32. All the constituents were at maximum concentration at the sand-gravel interface except alkalinity, chloride, and phosphate. Alkalinity peaked at the gravel-well interface, as did phosphates, and sulfates peaked 12 inches from the well casing.

Nitrogen content as N is shown on Plate 3-33. Maximum accumulation is retained in the soil at the sand gravel interface.

Coliform index was determined on tube influent and effluent as shown on Plate 3-34. Fifty percent of samples showed removal from MPN of 2500 to MPN of 500. Effluent samples went as high as 4500 MPN when influent was at 10,000 MPN.

Micro-photographs were taken of the tube contents after the 37 days of injection and compared with acid immersed samples of gravel pack and aquifer materials. These photographs are shown on Plates 3-35 to 3-37 inclusive. The samples after injection show the presence of a foreign substance, brownish in color as compared with the sharp clarity of the acid immersed samples.

STUDIES OF PERCOLATIVE CAPACITY OF THE SOIL

The well water levels observed during the period of filtered sewage effluent injection from November 1, 1966 to December 7, 1966 were used to make calculations for permeability of the aquifer between observation wells. The Thiem (for water table conditions) formula was used.

The variation of permeability with days after the start of injection between wells S-2 and S-3 and wells S-1 and S-2 are shown on Plate 3-1. The permeability up to 40 feet from the injection well decreased steadily although at a decreasing rate during the injection period.

The plot on Plate 3-2 shows that wells S-2 and S-3 which are furthest away from the injection well were affected the least.

The cumulative permeability loss with time is shown on Plate 3-3. The cumulative loss was greatest for wells S-1 and S-2 which are closest (5 feet to 15 feet) from the injection well as compared with S-2 and S-3 (15 feet to 40 feet) which are furthest from the injection well where velocities of injected water dispersion are less and dilution in the graound water of the injection water is greatest.

STUDIES OF SIMULATOR CONTENTS AS AFFECTING PERCOLATIVE CAPACITY

After being in use for about three years, the simulator contents were analyzed by sampling at four different levels in the saturated zone and at distances of four, nineteen, and thirty-seven inches from the injection well casing. During the three year period the simulator contents had been alternately injected with filtered sewage effluent, redeveloped with fresh water, allowed to remain saturated between injections and redevelopments and drained for winter periods.

The sample points are shown graphically in relation to the injection well on Plate 3-6

The samples were sieved for particle size and analyzed for COD, volatile solids, Nitrate, iron and Sulfate.

The sieve analyses are summarized on Plate 3-4. The result of the operations was to create a more uniform material by the addition of fines.

The analyses for constituents are summarized on Plate 3-6. In general, the concentrations were highest nearer the well although all constituents were present throughout. The average analyses with respect to distance from well casing are shown on Plate 3-5.

It is believed that the indications are that injection of filtered sewage effluent leaves organic and chemical residues in the soil in its path of travel.

CHANGES IN QUALITY OF PERCOLATING WATER BY REASON OF UNDERGROUND TRAVEL

Continued sampling of ground water in observation wells during the entire period from November 1965 to January 1968 has provided data on ground water quality changes during injection and during resting between injections. As of August 1967, the area of observations was increased from forty feet to 160 feet from the injection well.

The results of the observations are summarized on Plates 3-16 to 3-27 inclusive. Plates 3-11 to 3-15 inclusive which show coliform determination.

The observations indicate that during injection the effects are greatest nearest the injection well and diminish as the distance from the injection well increases. However, the effects of injected substances are apparent for 50 to 100 feet from the well based upon operations to date.

The injection periods are characterized by an increase in the following constituents of ground water:

MBAS
Phosphate
Specific Conductivity
Suspended Solids
Total Solids
Volatile Suspended Solids
Volatile Total Solids
COD
BOD
pH
Alkalinity
Coliform Bacteria
Ammonia and Nitrite

The injection periods are characterized by a lowering of the following constituents:

Nitrates
Total Nitrogen
Iron
Carbon dioxide

The resting periods are characterized by an increase of the following ground water constituents:

Iron
Sulfate
Nitrite
Nitrate
Ammonia

The resting periods between injections are characterized by a decrease in the following constituents in the ground water:

- COD
- BOD
- MBAS
- Phosphate
- Specific Conductivity
- Suspended Solids
- Volatile Suspended Solids
- Volatile Total Solids

Coliform bacteria increase in the ground water during injection determined as MPN. They tend to increase as distance from well increases during injection and tend to increase nearer the well during periods of resting.

The result of injection activities was to reduce the iron and carbon dioxide in the observation field compared with values observed in the original ground water before any injection took place.

CONCLUSIONS

1. The trickling filter effluent available at Riverhead represents an average equivalent of 60% purification of domestic sewage. This is of advantage to experimentation since the effects due to organic content are accelerated.

2. Heavy chlorination of filtered sewage effluent for recharge is undesirable because it produces excessive chlorides and chlorine compounds, increases turbidity and creates oxidizing potential tending toward increase in dissolved salts. (See Plate D) It is also possible that soil clogging is accelerated

because beneficial organisms are destroyed or inhibited.

3. The infiltrative interface of the soil is progressively clogged in greater degree by successive applications of filtered sewage effluent. (See Plate C) Design of recharge wells should provide for renewability of the interface.

4. The percolative capacity of the soil mantle is affected by the travel of filtered sewage effluent. In this particular case, the loss of capacity was 63% five to fifteen feet from the injection well and 51 percent 15 to 40 feet from the injection well. Percolative capacity loss increases with time of injection (See Plate 3-3).

5. Application of filtered sewage effluent to the soil mantle at the research site produces organic and inorganic residues in the soil percolative path, which, upon drying and sieving, have the effect of producing an aquifer with greater uniformity coefficient and a greater content of finer particles. (See Plate 3-4)

6. Residues which remain in the soil after recharge, include COD, volatile solids, Nitrates, Nitrites, Ammonia, iron, sulfates, Phosphates. Those retained in highest degree are Nitrates, Phosphates and sulfates.

7. Coliform bacteria tend to increase as distance from the well increases during injection and tend to increase nearer the well during periods of resting between injections.

8. During resting periods between injections, the nitrogen, sulfate and iron content of the ground water in the observation wells rises dramatically. It is possible that this could be due to deamination of live and dead organisms resulting from the recharge of organic materials and the production of sulfates by micro-organisms.

9. More complete oxidation of organic material by biological treatment and removal of nutrient materials, together with suitable injection well design, would provide feasible waste water renovation via artificial recharge.

10. A pilot operation with higher degree of biological treatment and nutrient removal would be of advantage.

Respectfully submitted,

John J. Baffa

John J. Baffa,
Consulting Engineer

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

WATER LEVEL IN GROUND WELLS DURING FILTERED SEWAGE EFFLUENT INJECTION AT 20 GPM (JULY 19 TO AUGUST 23, 1967)

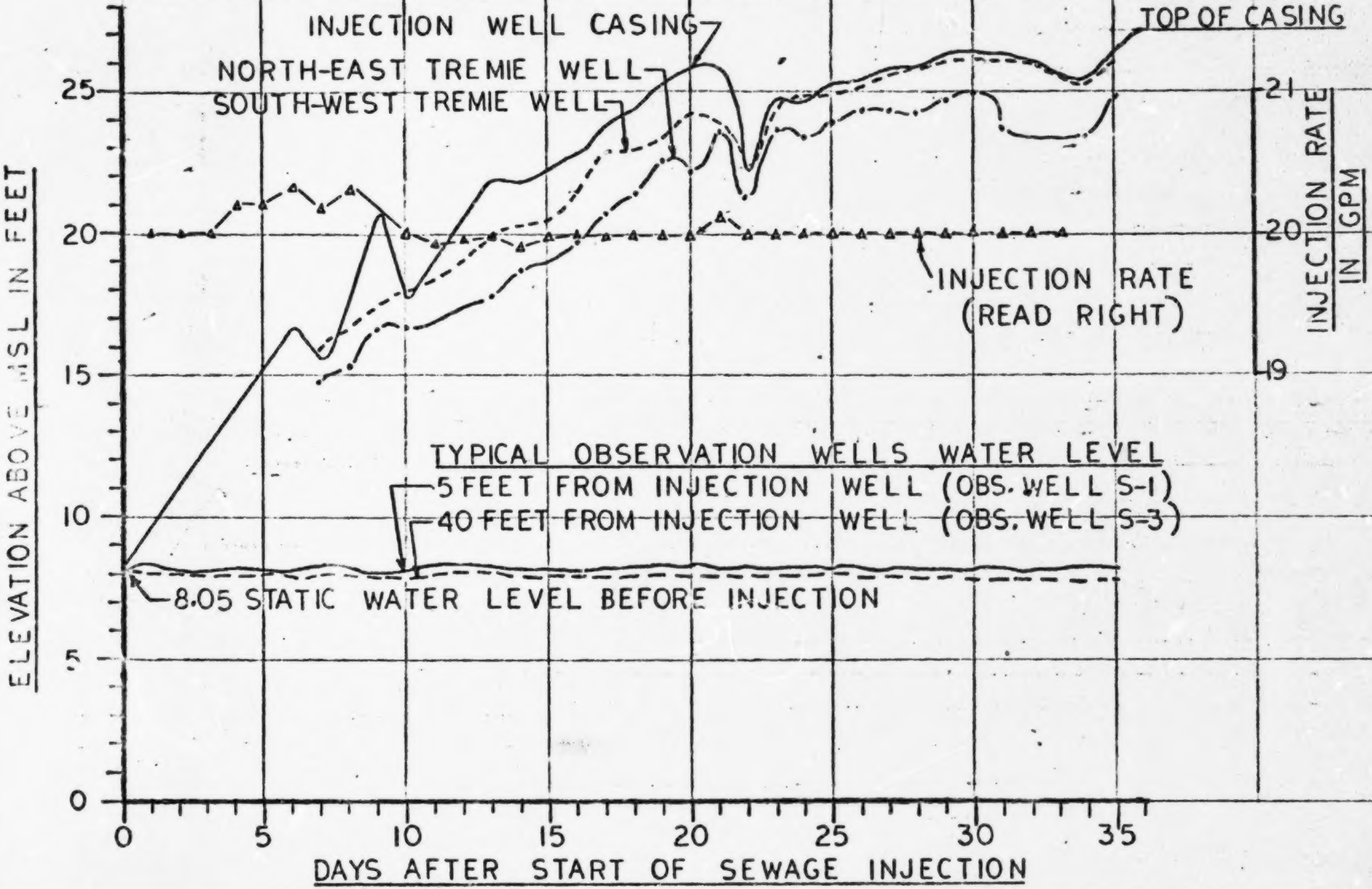
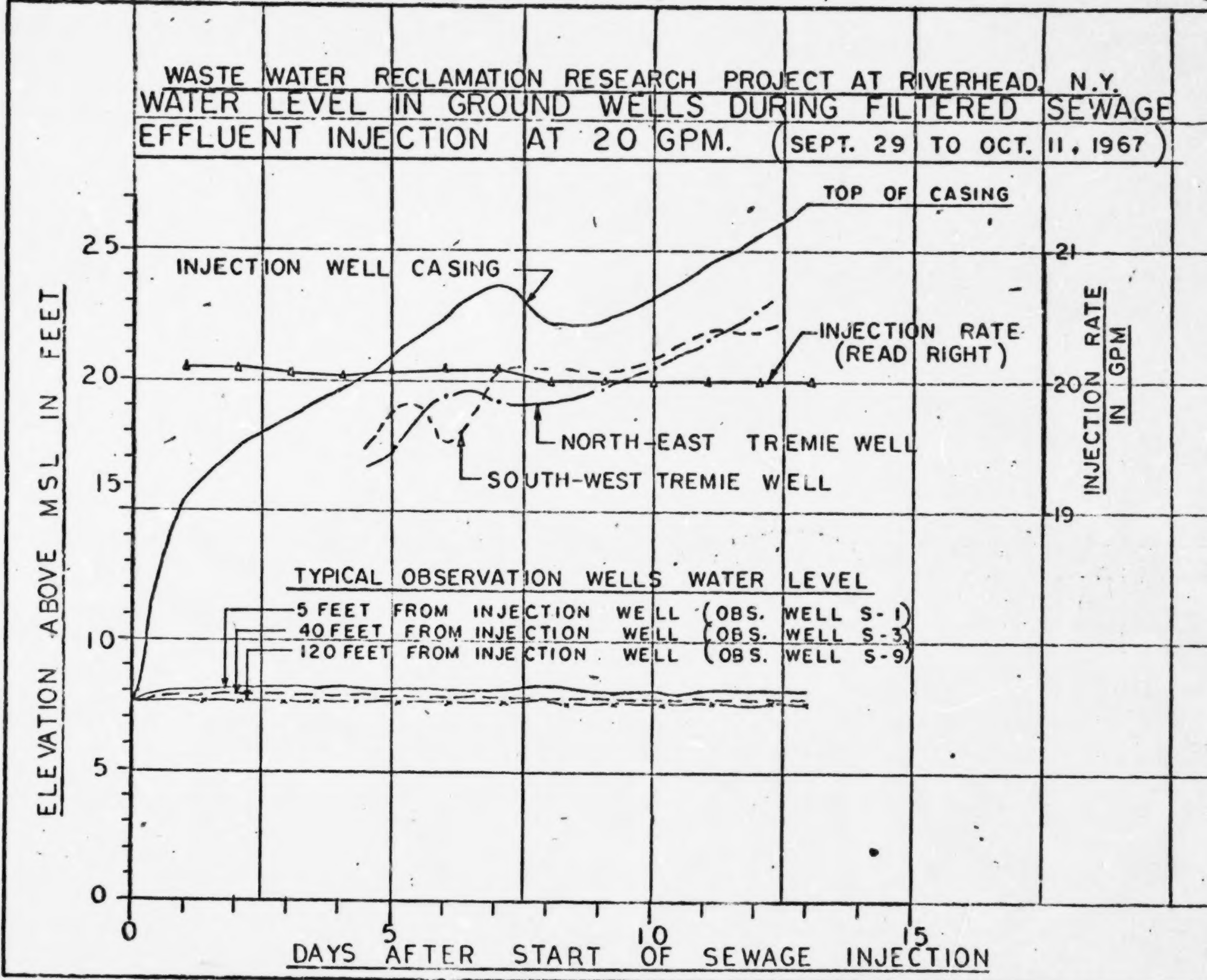


PLATE A



WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.
WATER LEVEL IN GROUND WELLS DURING FILTERED SEWAGE EFFLUENT INJECTION AT 20 GPM. (SEPT. 29 TO OCT. 11, 1967)

PLATE B

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.
RISE IN WATER LEVELS IN GROUND INJECTION WELL DURING FRESH WATER AND FILTERED SEWAGE EFFLUENT INJECTION AT 20 GPM (1966 & 1967)

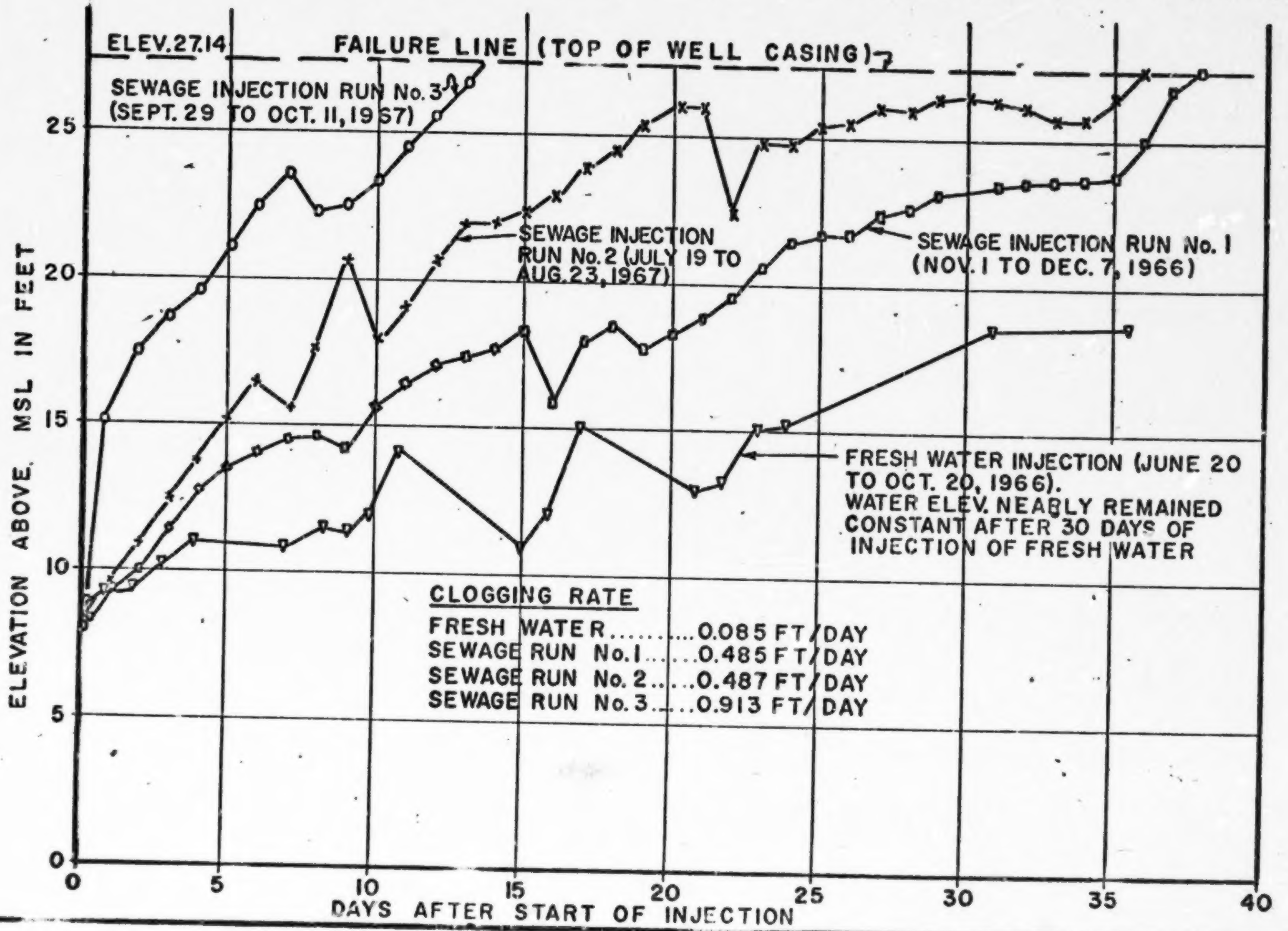
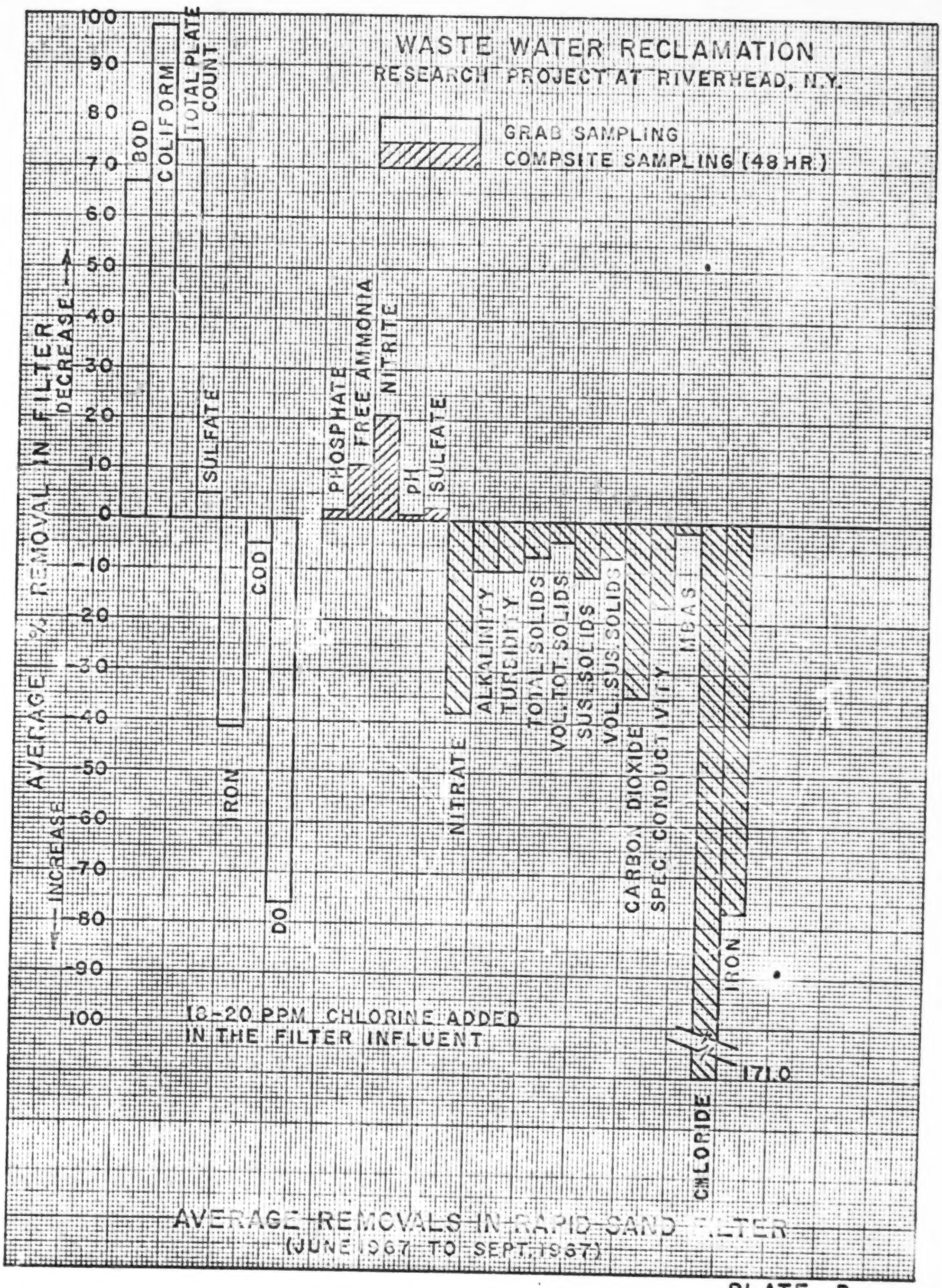


PLATE C



WASTE WATER RECLAMATION
RESEARCH PROJECT AT RIVERHEAD, N.Y.

AVERAGE REMOVALS IN RAPID SAND FILTER
(JUNE 1967 TO SEPT. 1967)

K&E 10 X 10 TO THE CENTIMETER 46 1513
18 X 25 CM. MADE IN U.S.A.
KEUFFEL & ESSER CO.

PLATE D

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

CHANGE OF PERMEABILITY AS SHOWN BY OBSERVATION WELL LEVELS DURING FILTERED SEWAGE INJECTION (NOV. 1, 1966 TO DEC. 7, 1966)

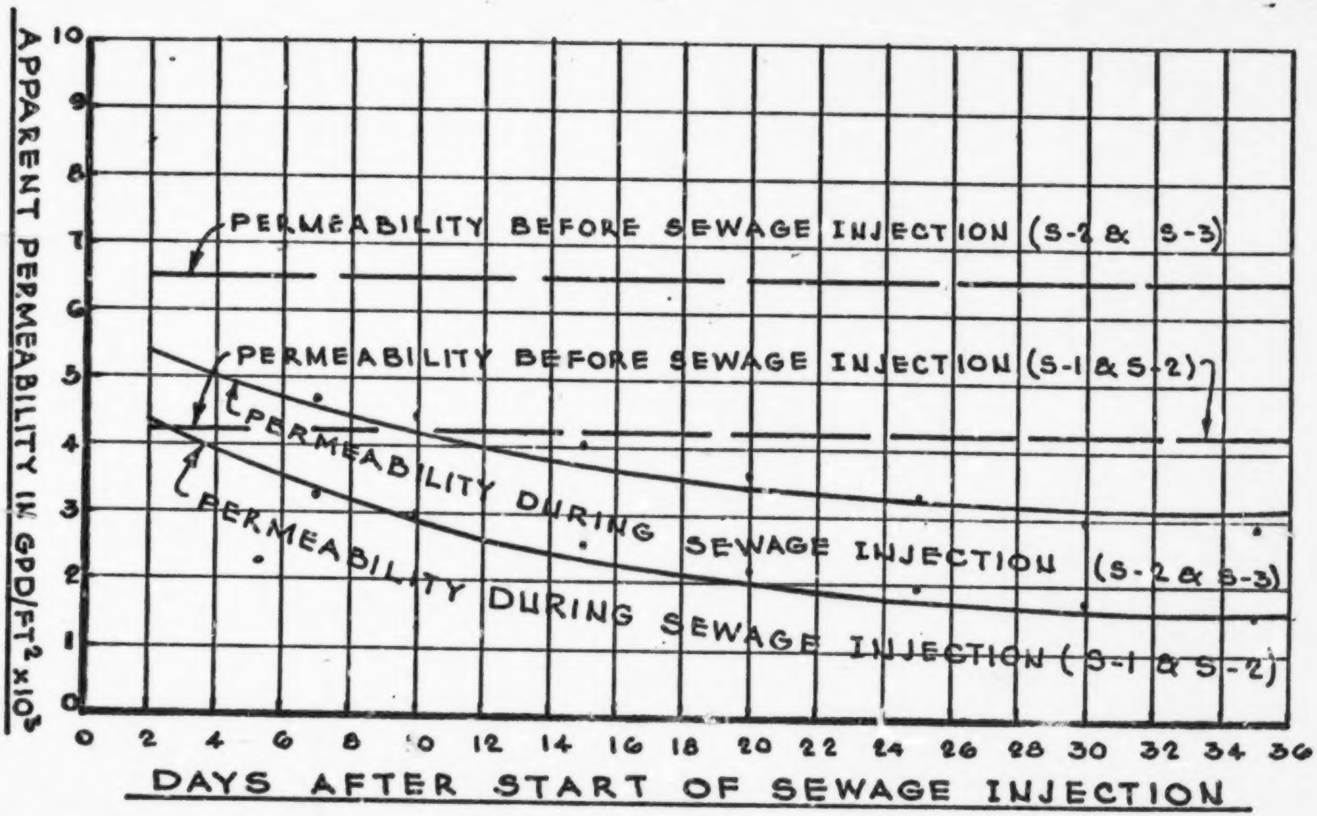
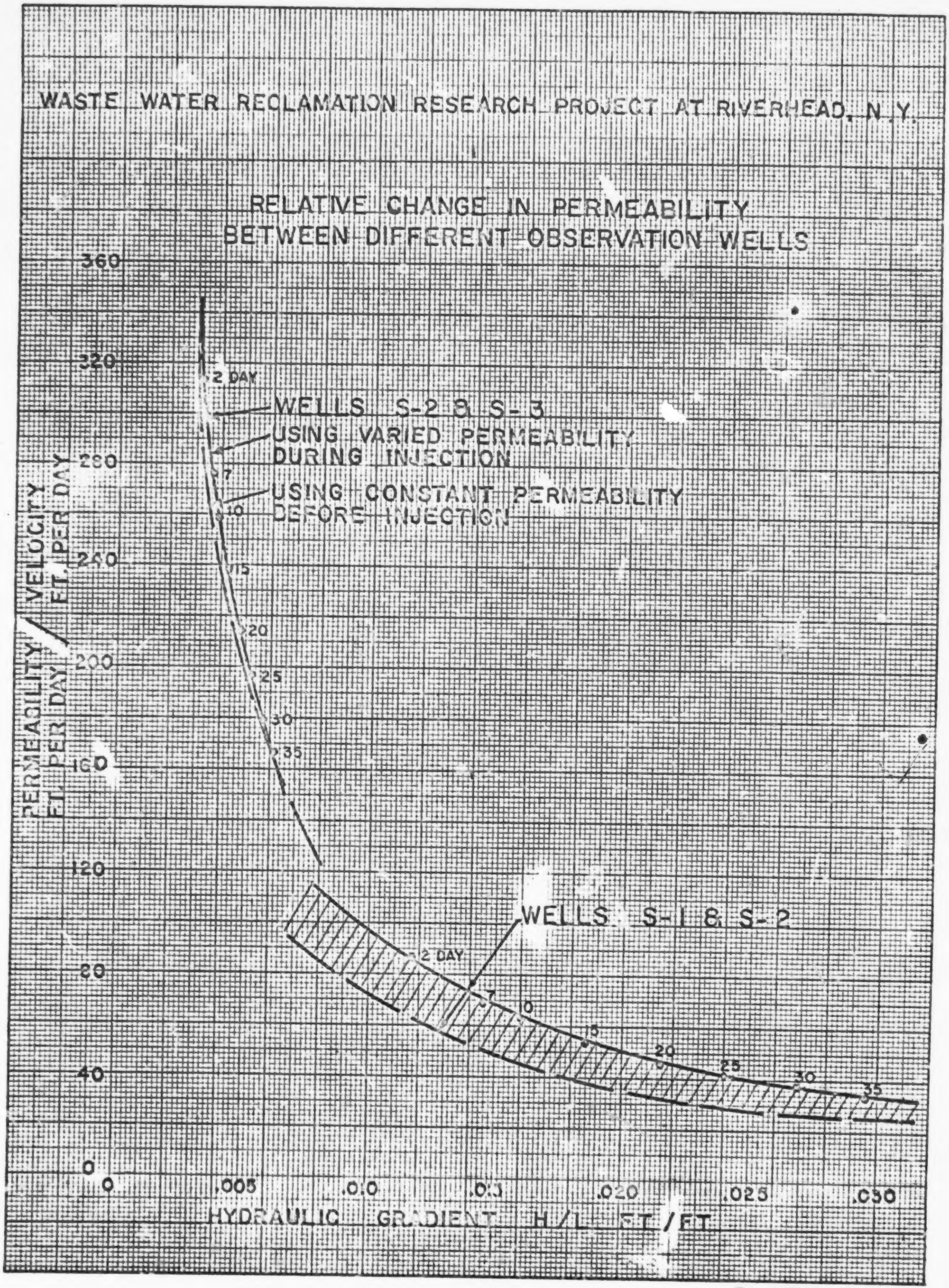


PLATE 3-1



WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

RELATIVE CHANGE IN PERMEABILITY BETWEEN DIFFERENT OBSERVATION WELLS

PLATE 3-2

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. 46 1513 MADE IN U.S.A. KEUFFEL & ESSER CO.

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

APPARENT CUMULATIVE LOSS OF PERCOLATIVE CAPACITY OF AQUIFER DURING FILTERED SEWAGE INJECTION (NOV. 1, 1966 TO DEC. 7, 1966.)

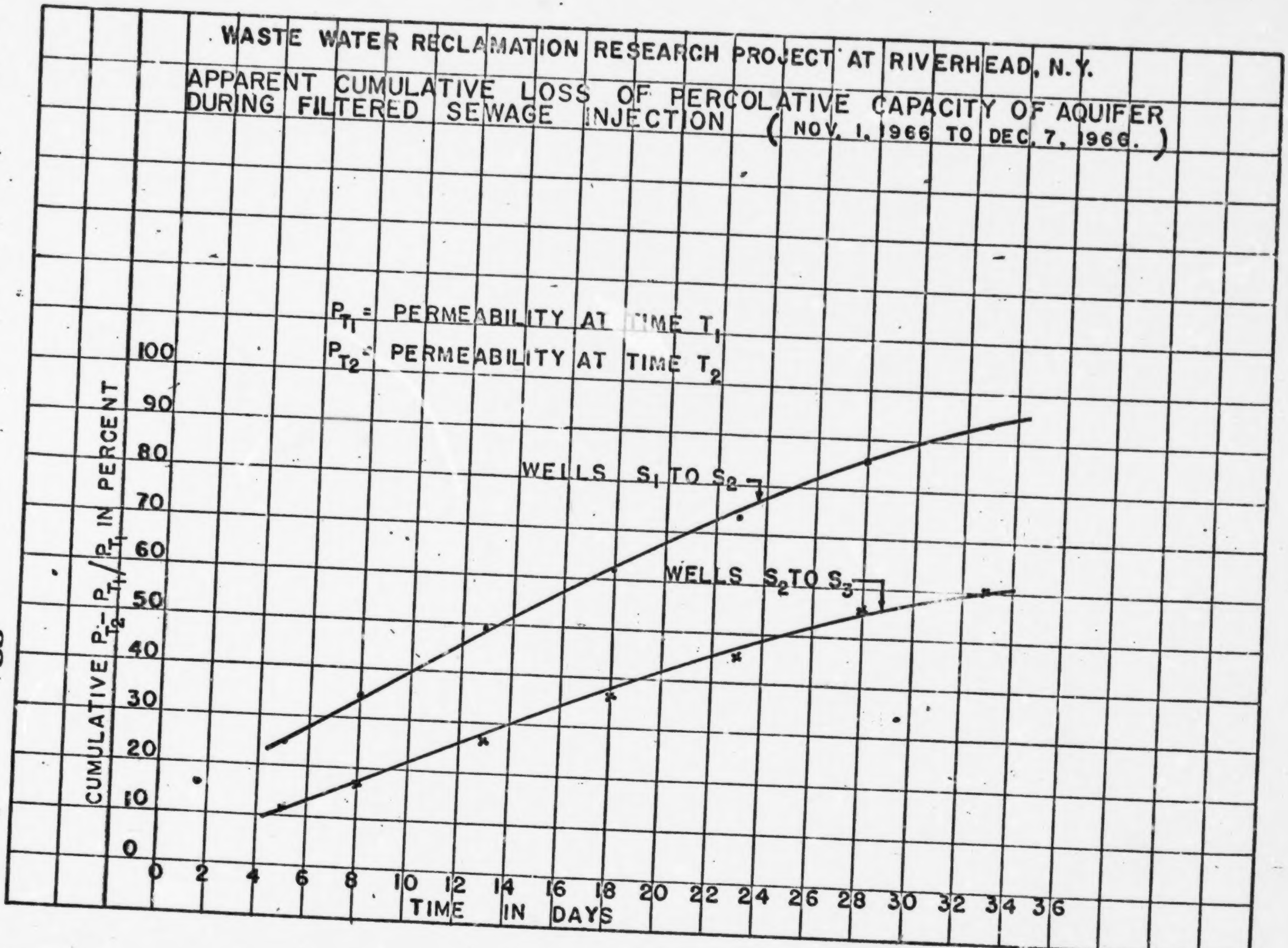


PLATE 3 – 3

K&E SEMI-LOGARITHMIC 46 5493
KEUFFEL & ESSER CO.

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

SIEVE ANALYSIS

GRADATION OF AQUIFER PARTICLE SIZE

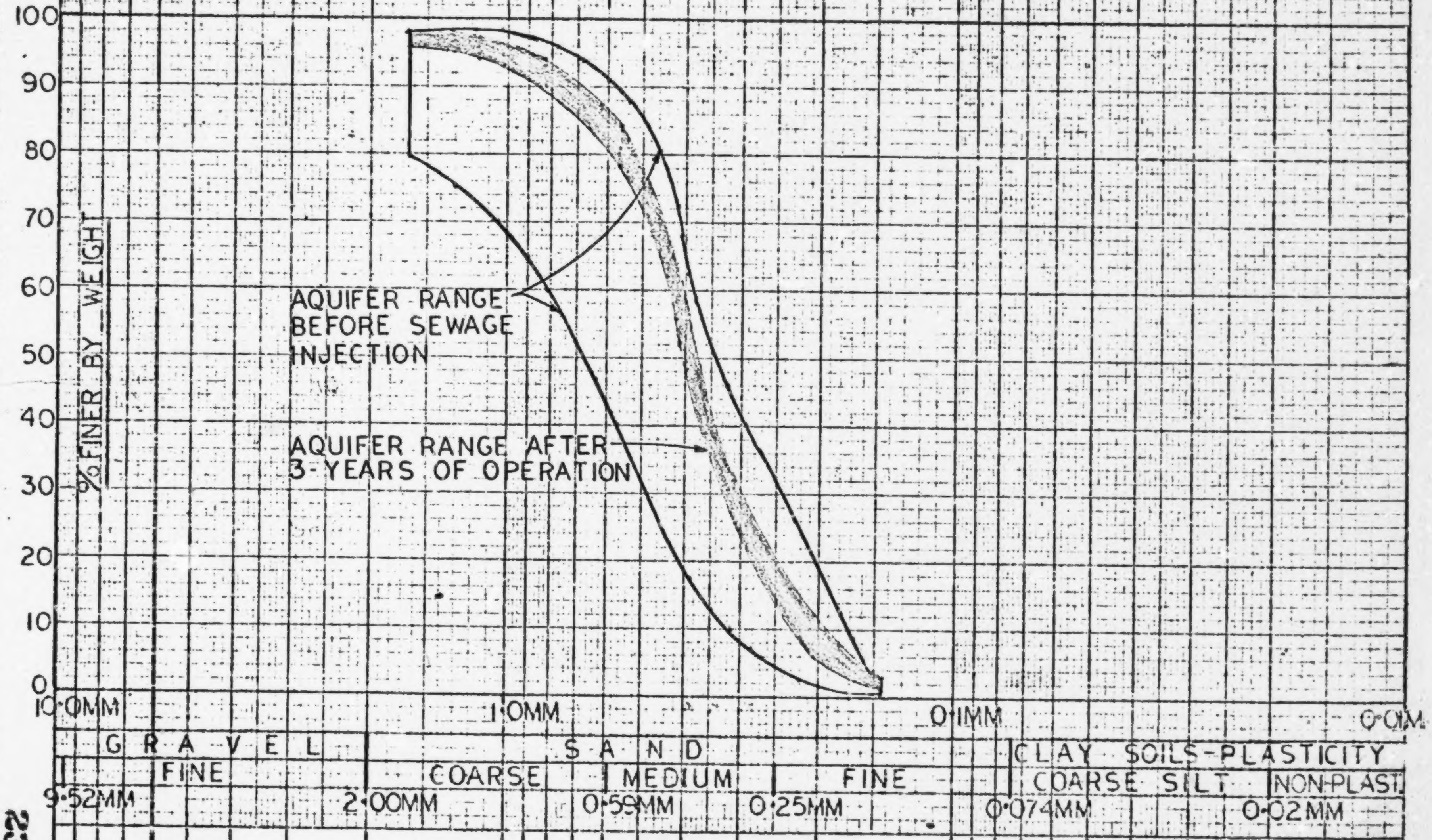


PLATE 3-4

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

ANALYSIS OF SIMULATOR AQUIFER CONTENTS AFTER 3 YEARS OF OPERATION

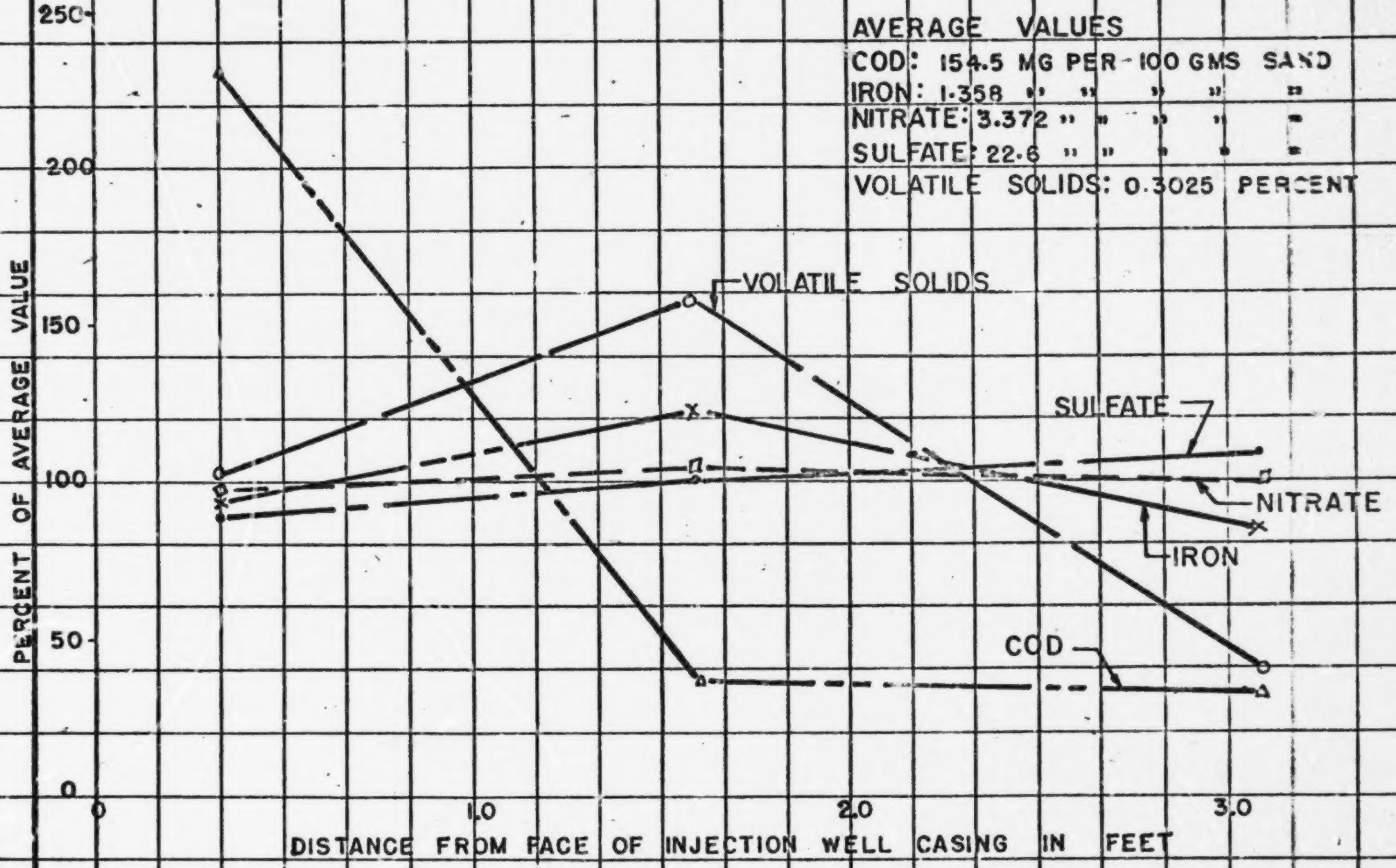
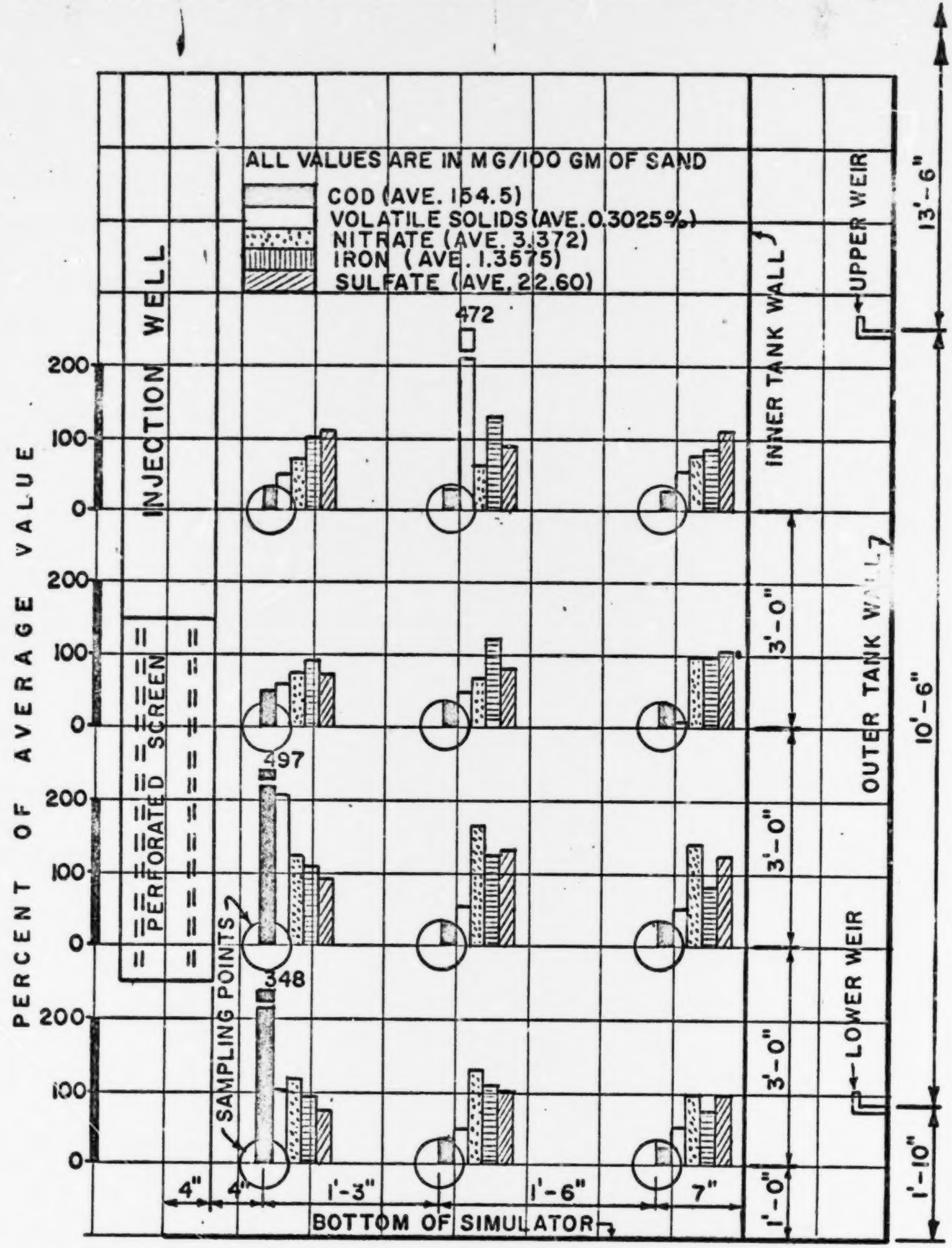

AVERAGE VALUES
COD: 154.5 MG PER-100 GMS SAND
IRON: 1.358 " " " " "
NITRATE: 3.372 " " " " "
SULFATE: 22.6 " " " " "
VOLATILE SOLIDS: 0.3025 PERCENT

PLATE 3-5

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.



CHEMICAL ANALYSES OF SIMULATOR AQUIFER CONTENTS AT POINTS AFTER 3-YEARS OF OPERATION

PLATE 3-6

K+E SEMI-LOGARITHMIC 46 5493
KEUFFEL & ESSER CO.

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

SIEVE ANALYSIS

SIMULATOR SAMPLING TUBE (WEST)
AFTER 5 DAYS INJECTION OF FILTERED SEWAGE (SATURATED CONDITION)
JULY 19 TO 24, 1967

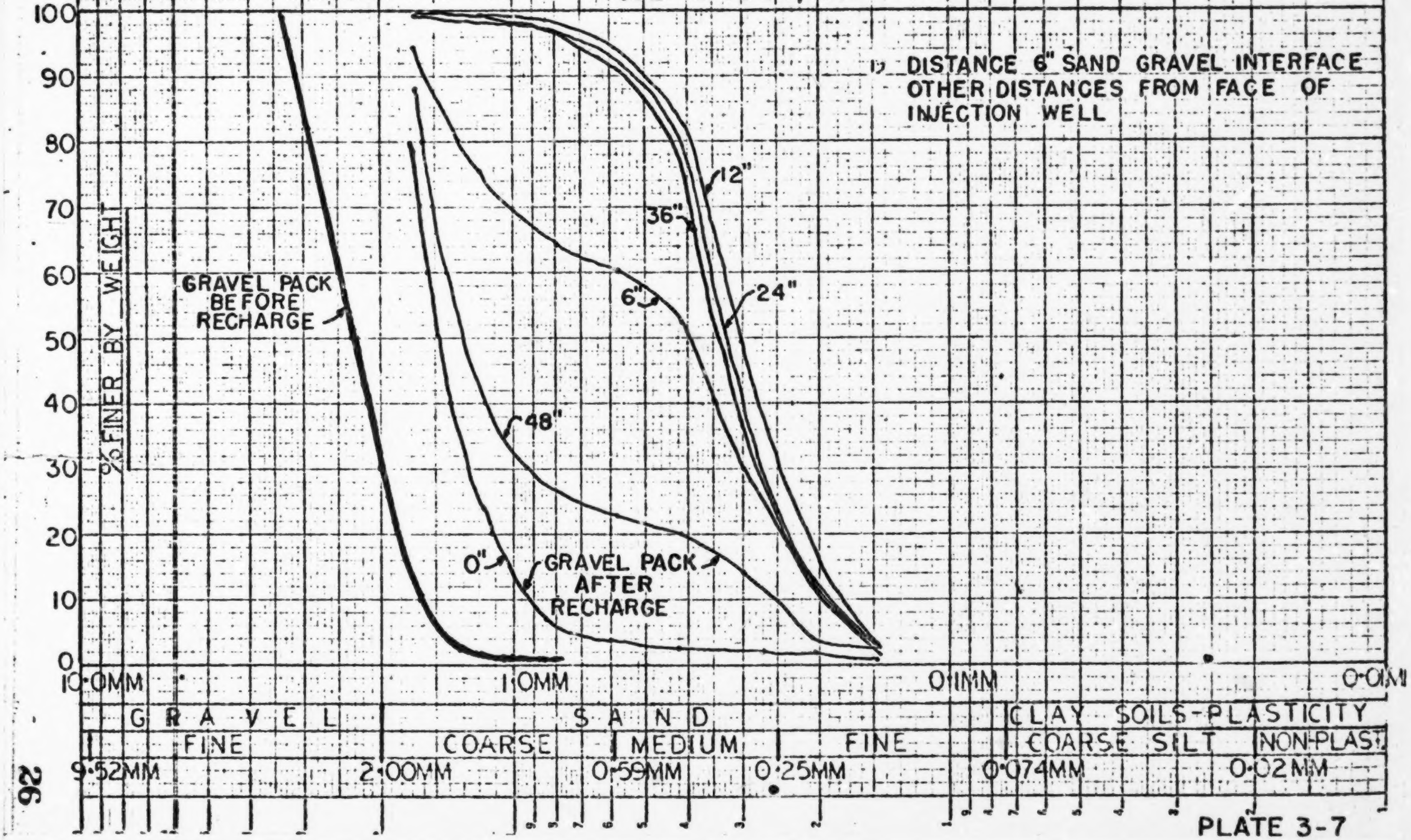


PLATE 3-7

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

ANALYSIS OF AQUIFER MATERIALS IN SIMULATOR SAMPLING TUBE AFTER 5 DAYS INJECTION OF FILTERED SEWAGE (SATURATED CONDITION)

(JULY 19, 1967 TO JULY 24, 1967)

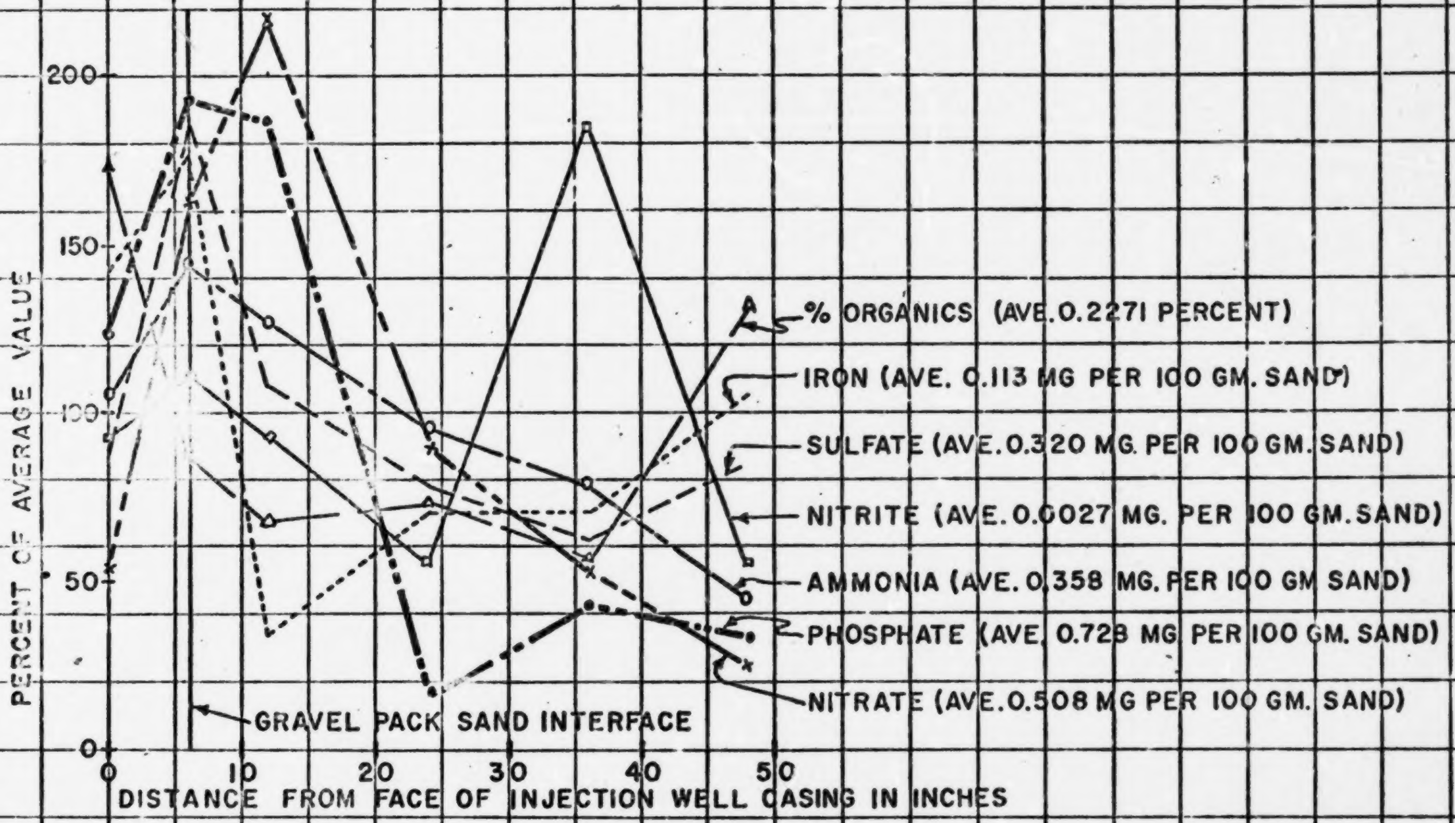
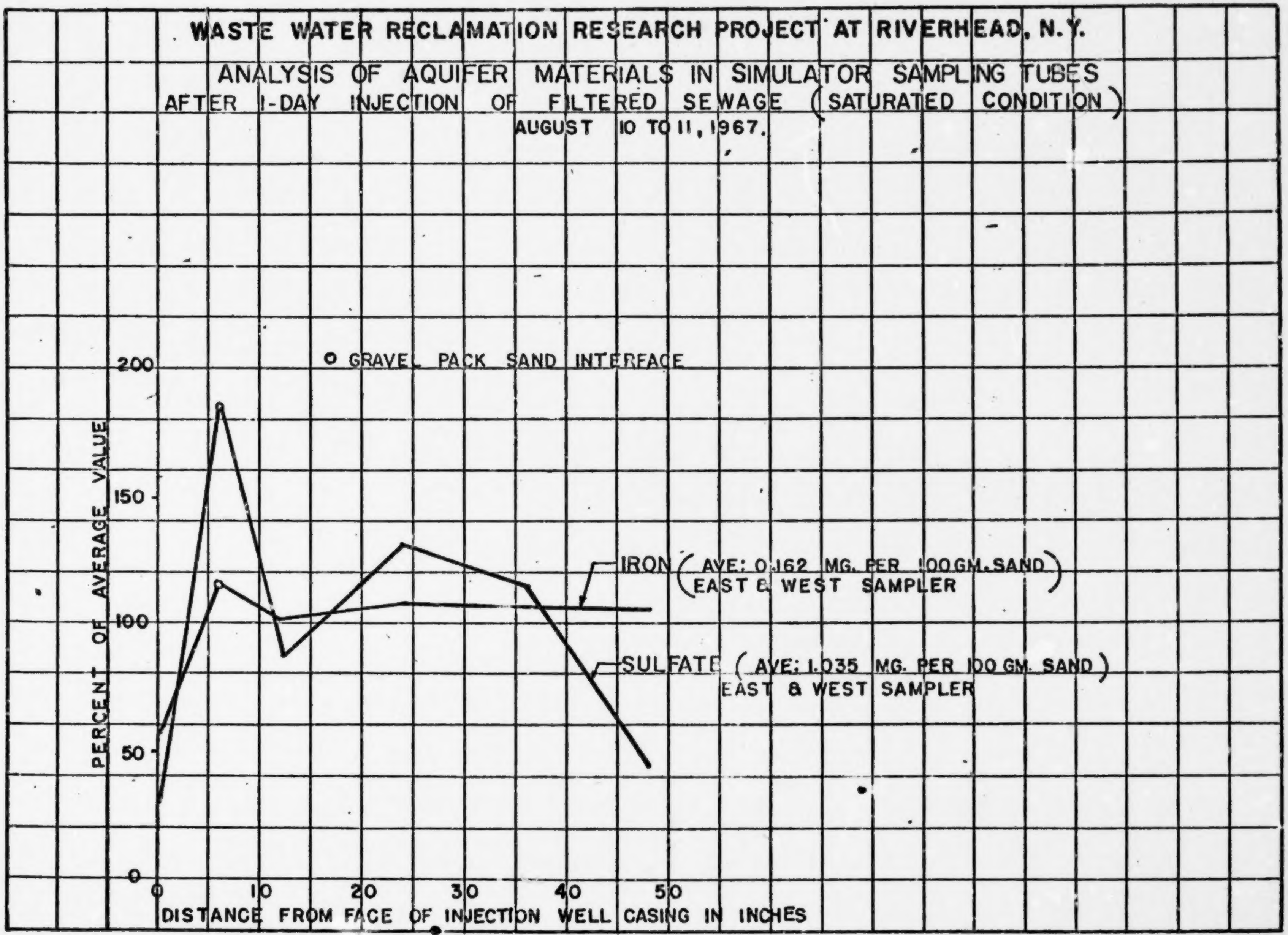


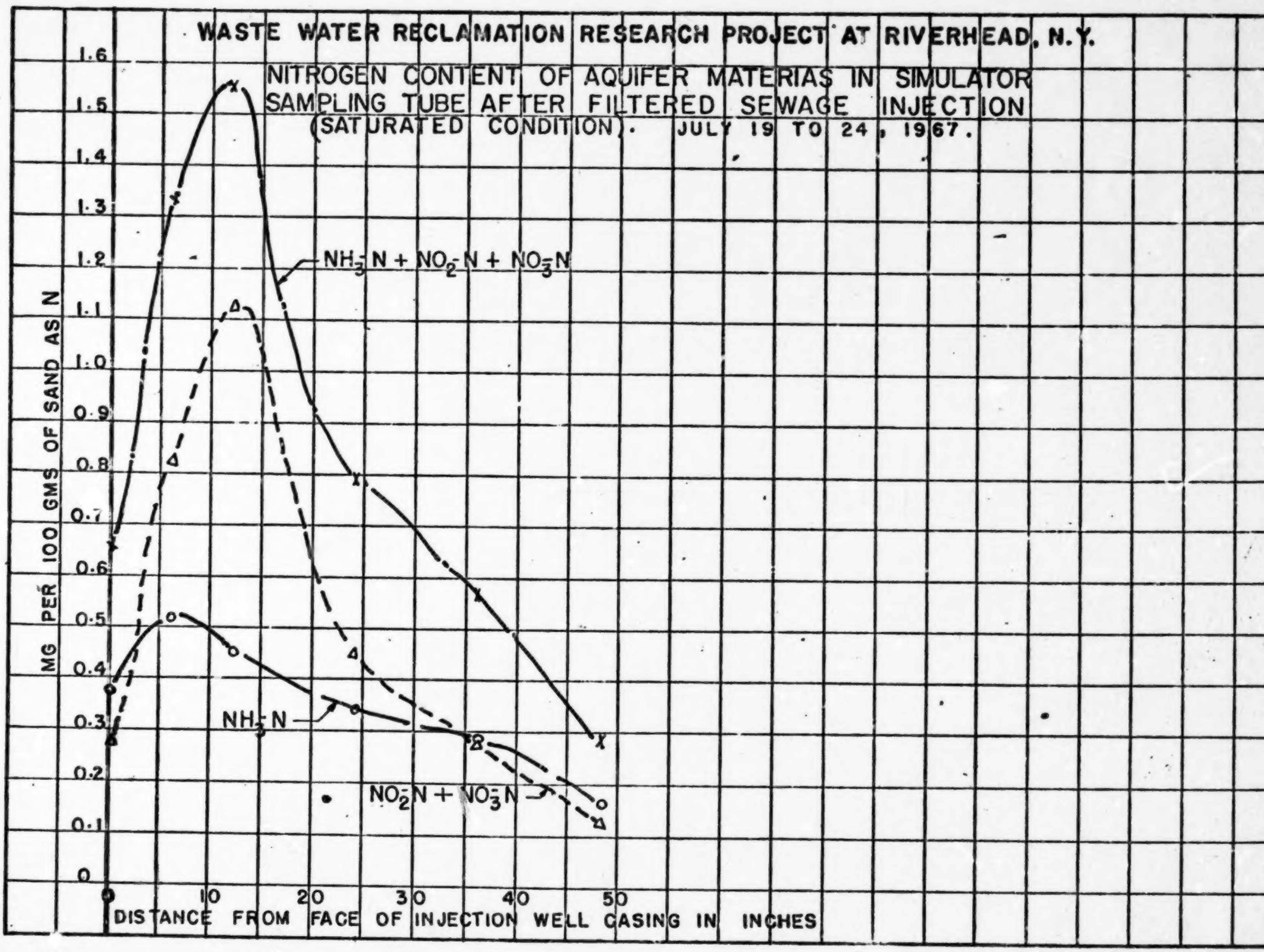
PLATE 3-8



WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

ANALYSIS OF AQUIFER MATERIALS IN SIMULATOR SAMPLING TUBES
AFTER 1-DAY INJECTION OF FILTERED SEWAGE (SATURATED CONDITION)
AUGUST 10 TO 11, 1967.

PLATE 3-9

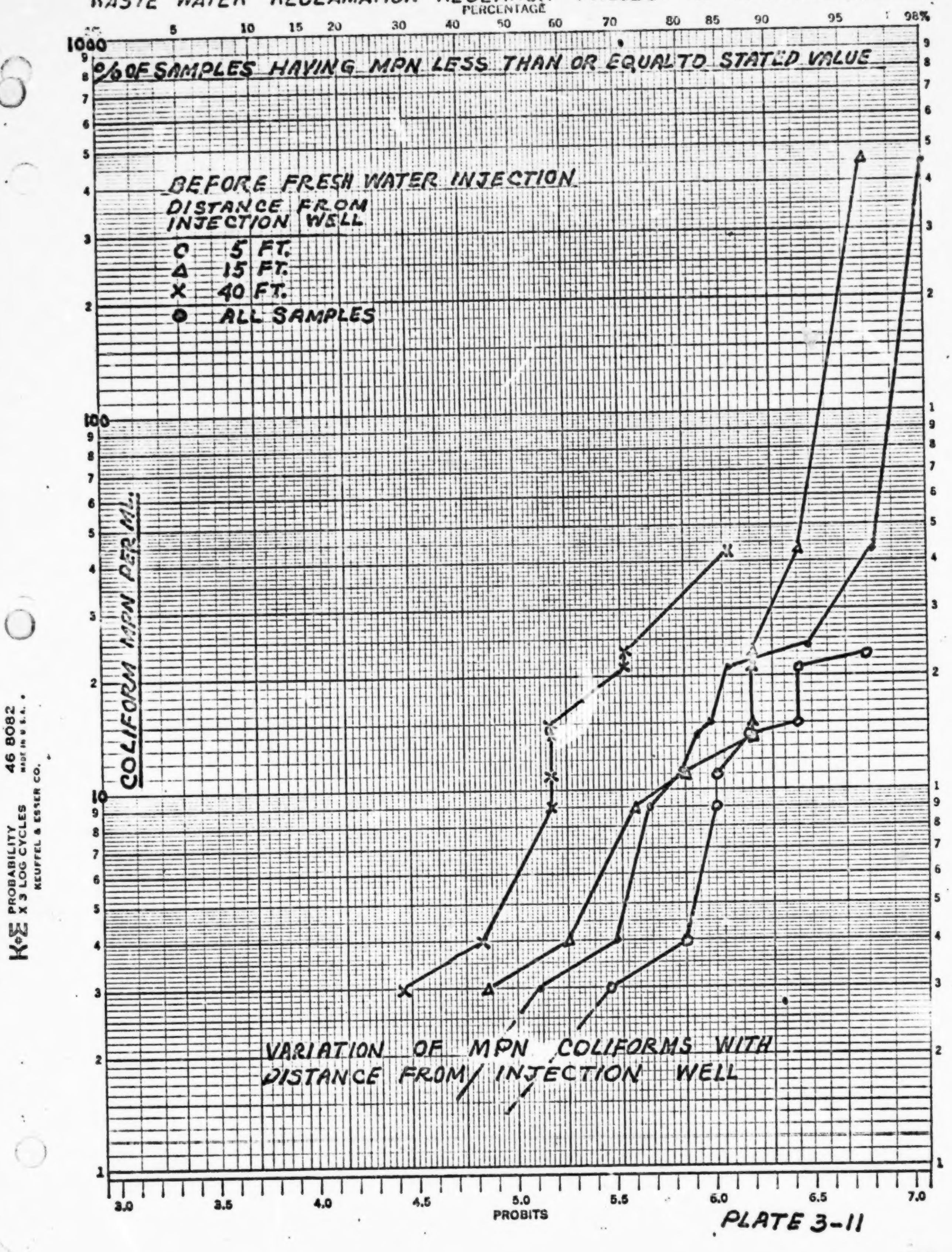


WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

NITROGEN CONTENT OF AQUIFER MATERIAS IN SIMULATOR SAMPLING TUBE AFTER FILTERED SEWAGE INJECTION (SATURATED CONDITION). JULY 19 TO 24, 1967.

PLATE 3-10

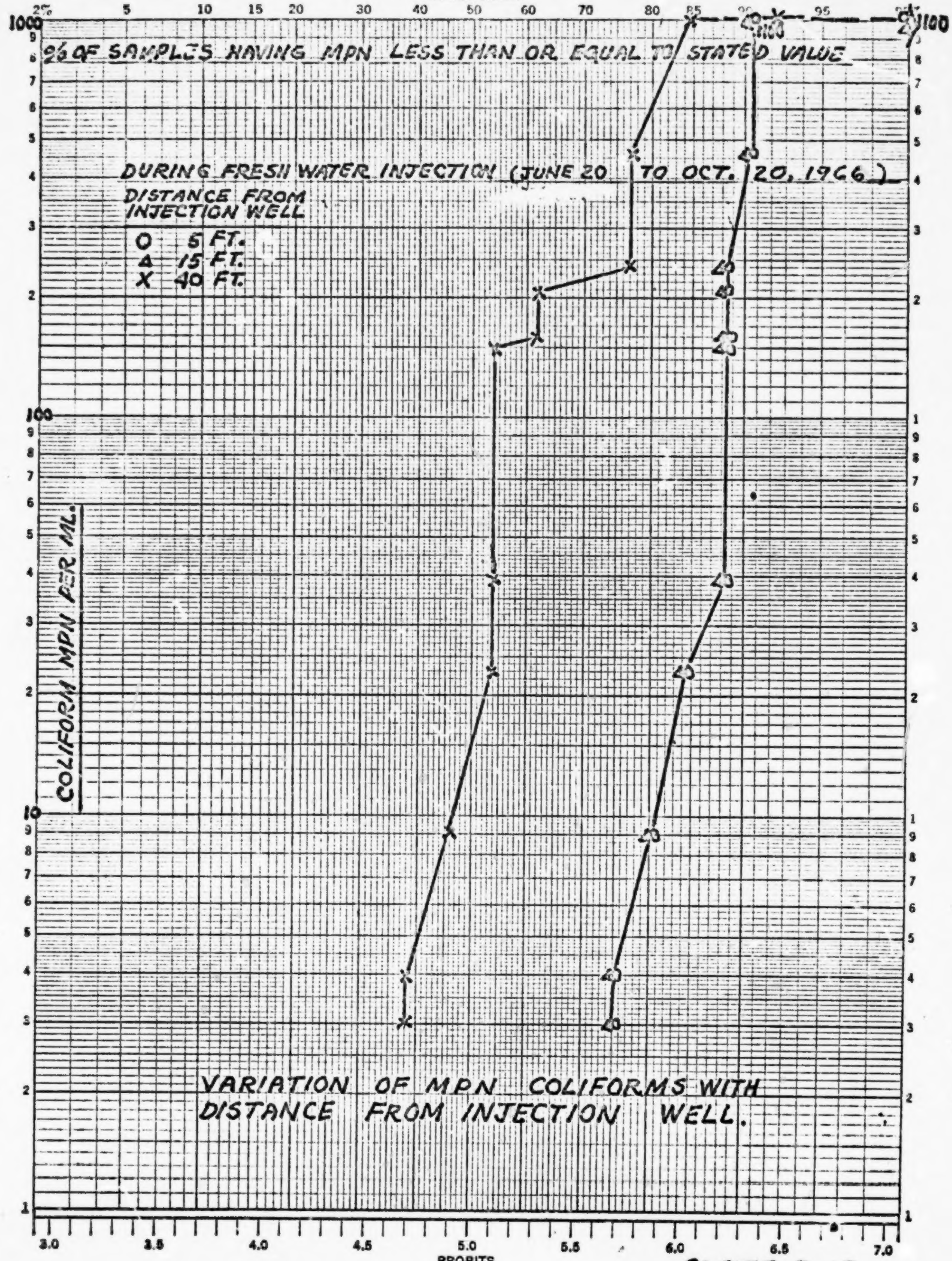
WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.



VARIATION OF MPN COLIFORMS WITH DISTANCE FROM INJECTION WELL

PLATE 3-11

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.



VARIATION OF MPN COLIFORMS WITH DISTANCE FROM INJECTION WELL.

PLATE 3-12

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

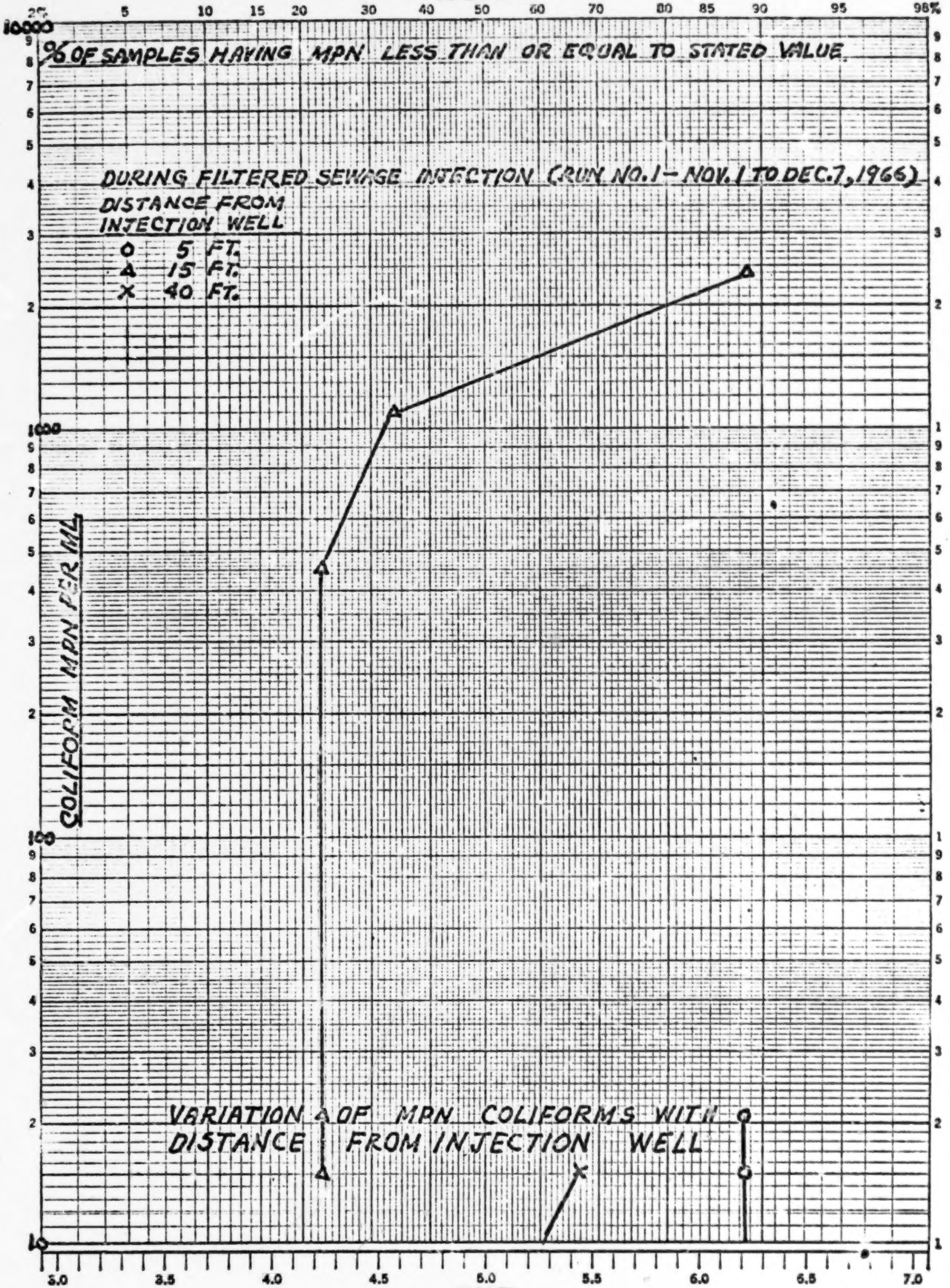


PLATE 3-13

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N. Y.

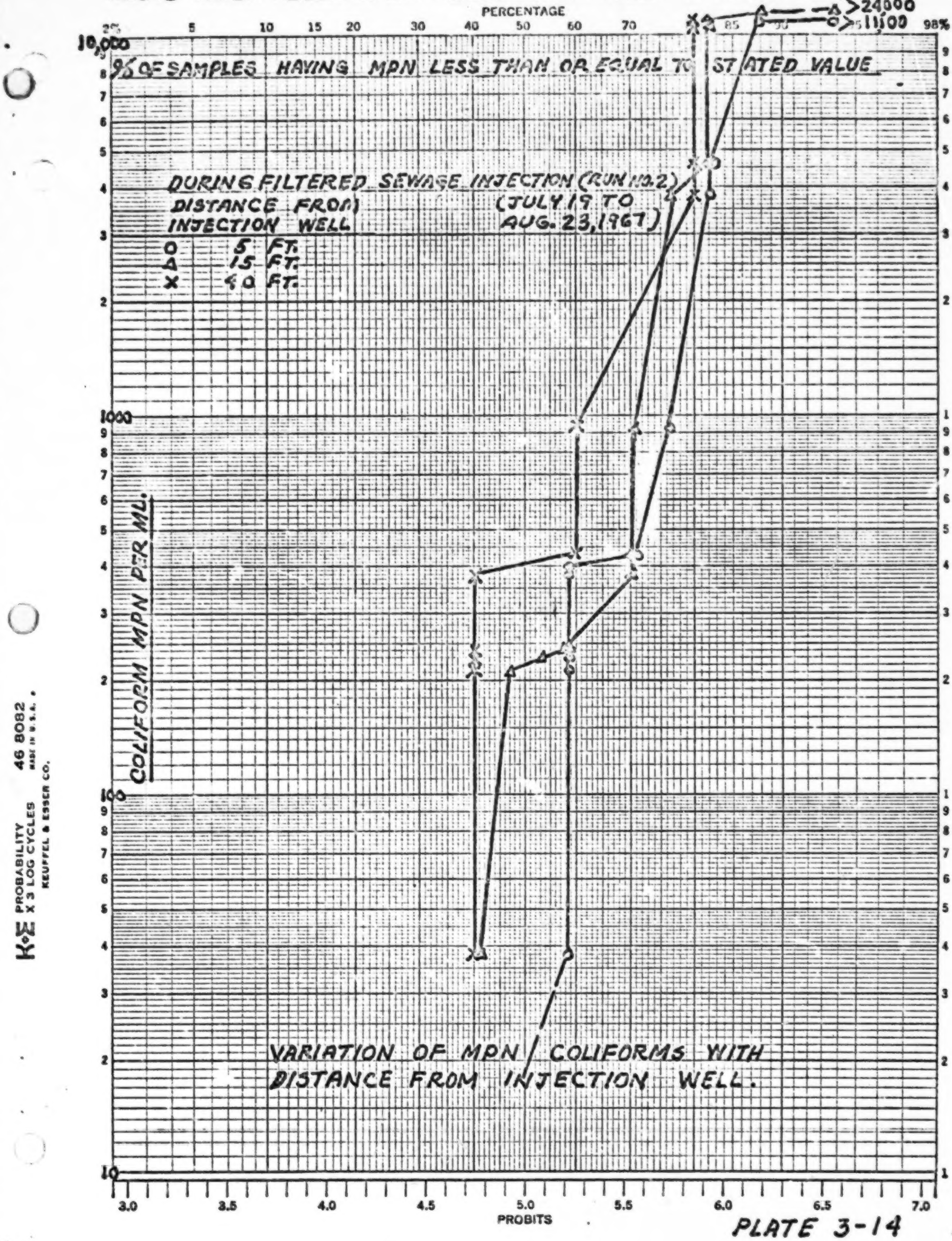
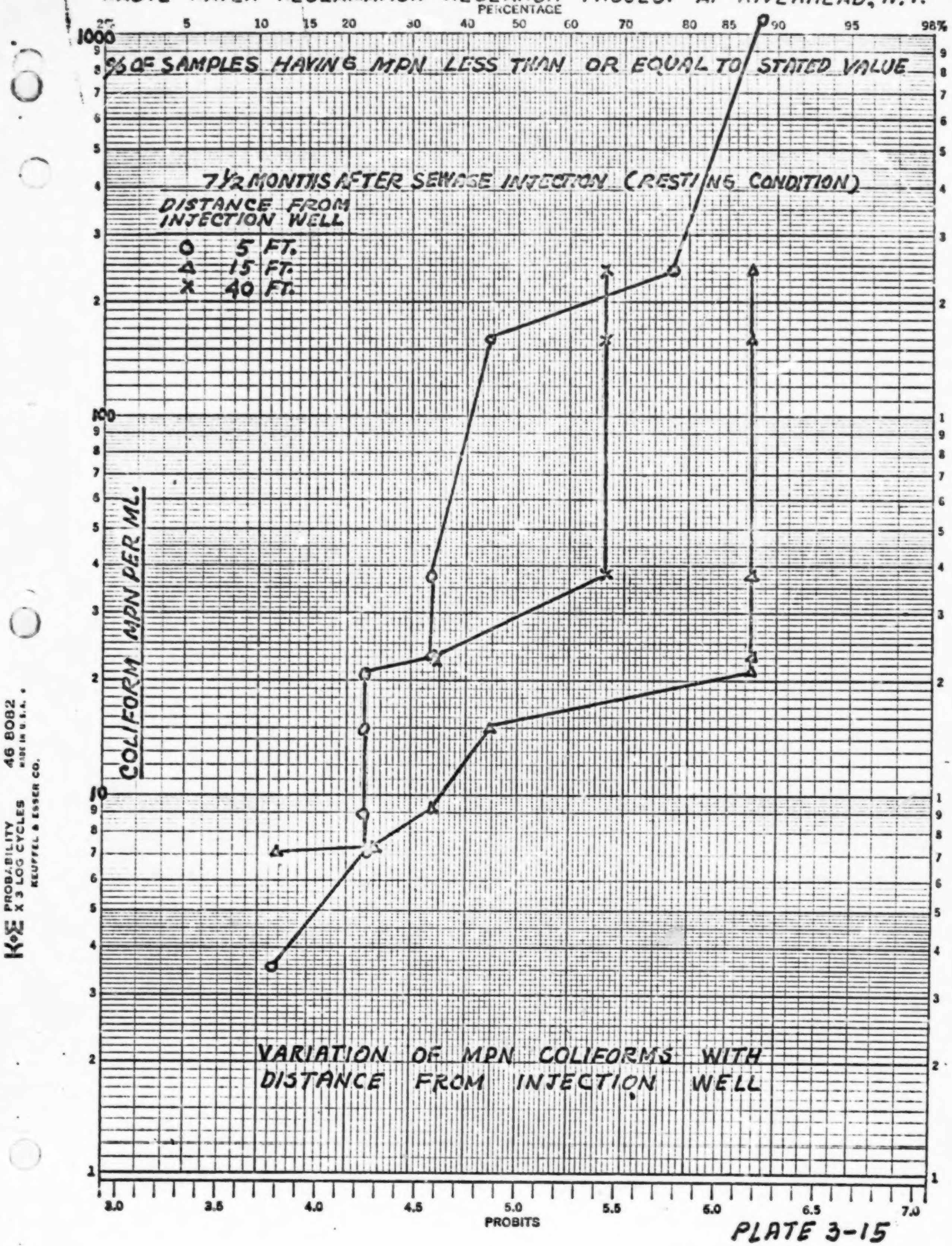


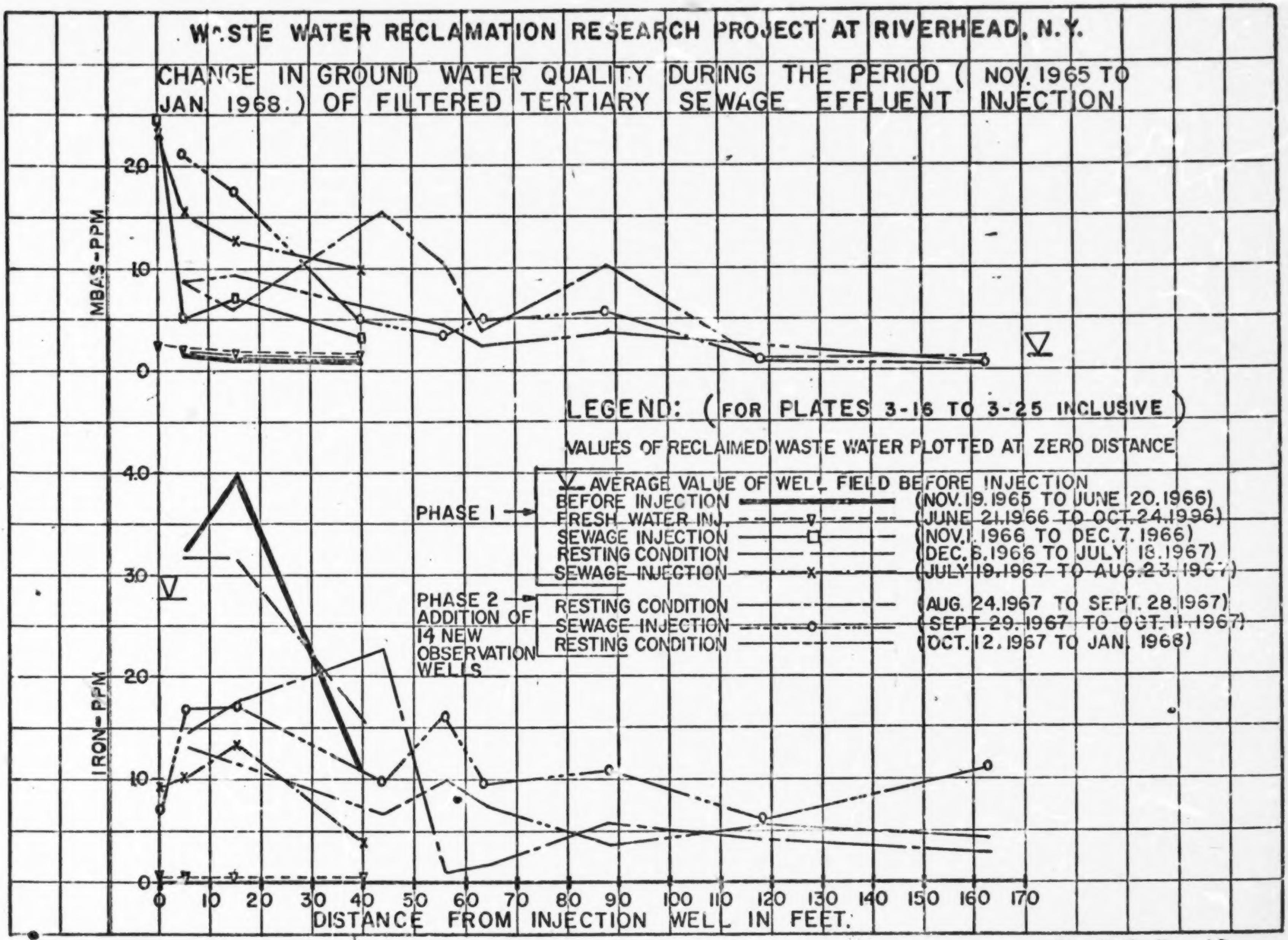
PLATE 3-14

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.



VARIATION OF MPN COLIFORMS WITH DISTANCE FROM INJECTION WELL

PLATE 3-15



WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

CHANGE IN GROUND WATER QUALITY DURING THE PERIOD (NOV. 1965 TO JAN. 1968.) OF FILTERED TERTIARY SEWAGE EFFLUENT INJECTION.

PLATE 3 – 16

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

CHANGE IN GROUND WATER QUALITY DURING THE PERIOD (NOV. 1965 TO JAN. 1968.) OF FILTERED TERTIARY SEWAGE EFFLUENT INJECTION.

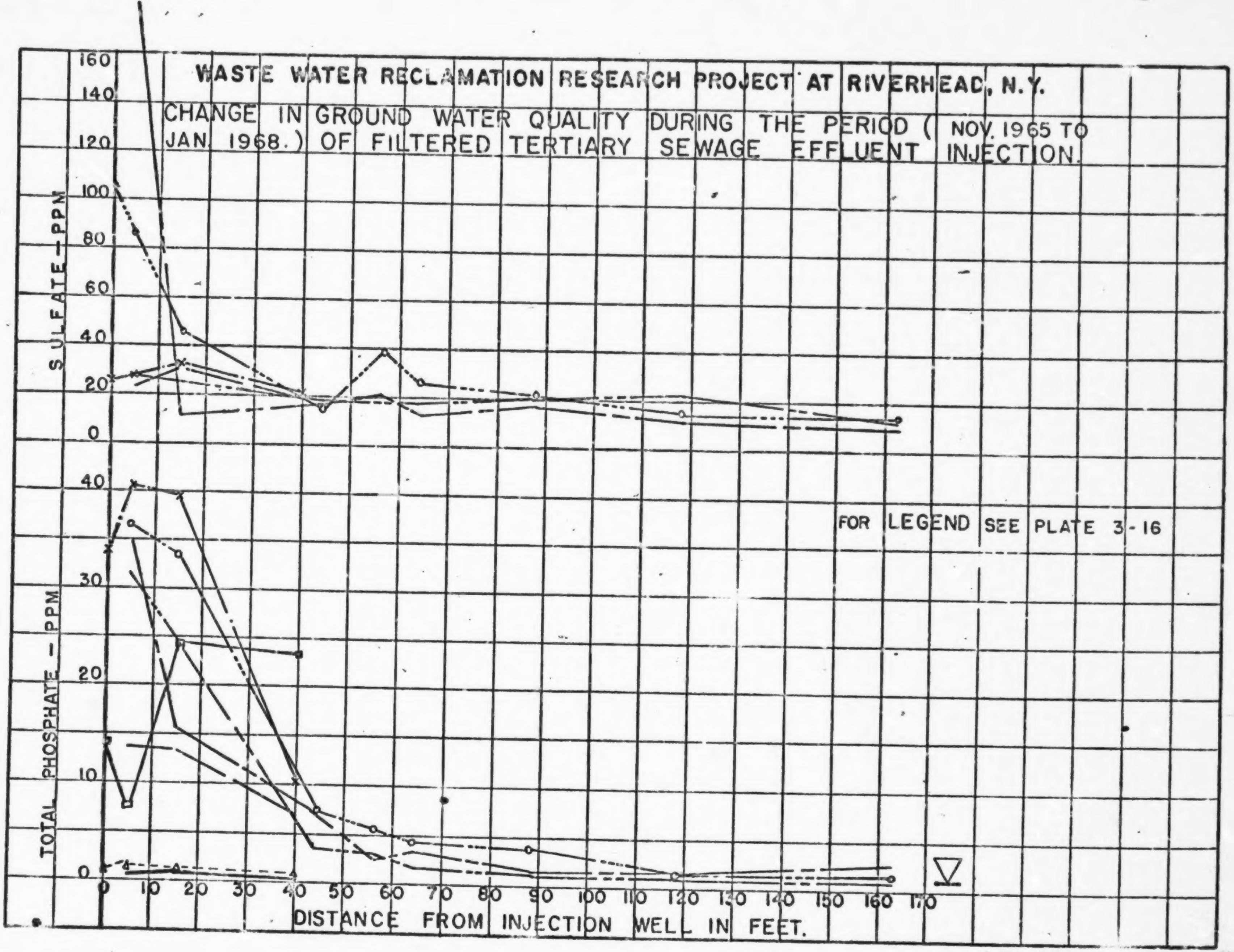
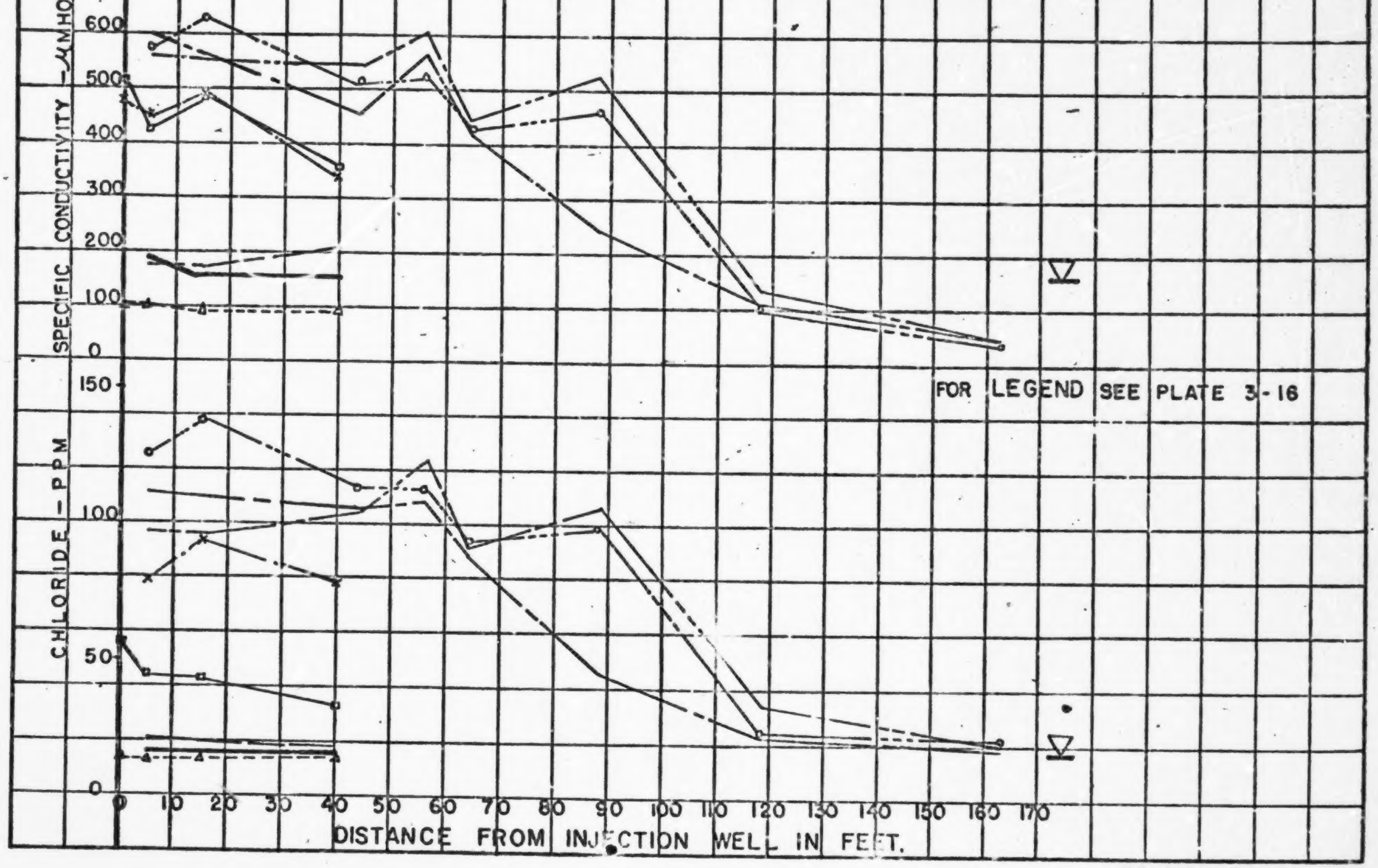


PLATE 3-17

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

CHANGE IN GROUND WATER QUALITY DURING THE PERIOD (NOV. 1965 TO JAN. 1968.) OF FILTERED TERTIARY SEWAGE EFFLUENT INJECTION.

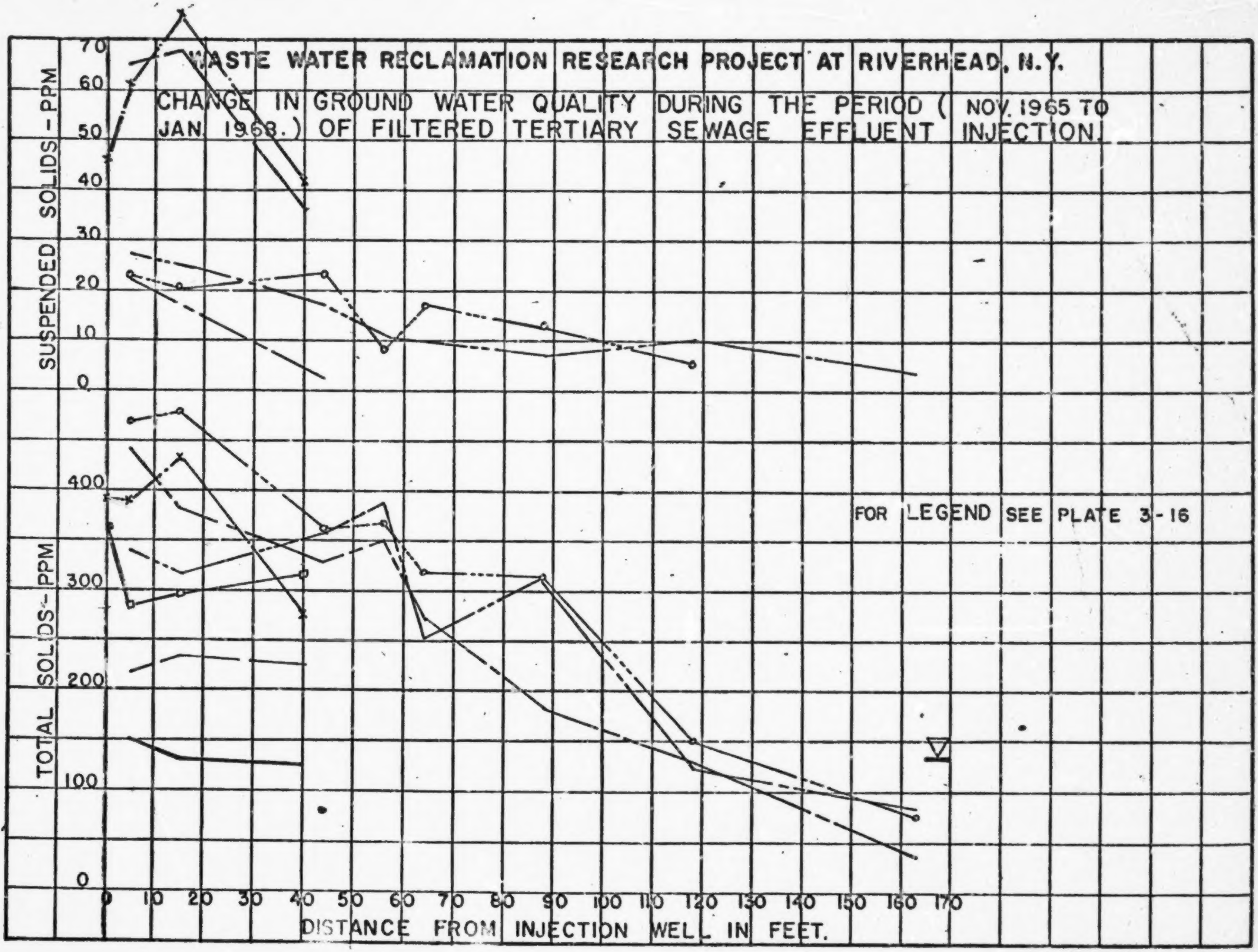


FOR LEGEND SEE PLATE 3-16

PLATE 3-18

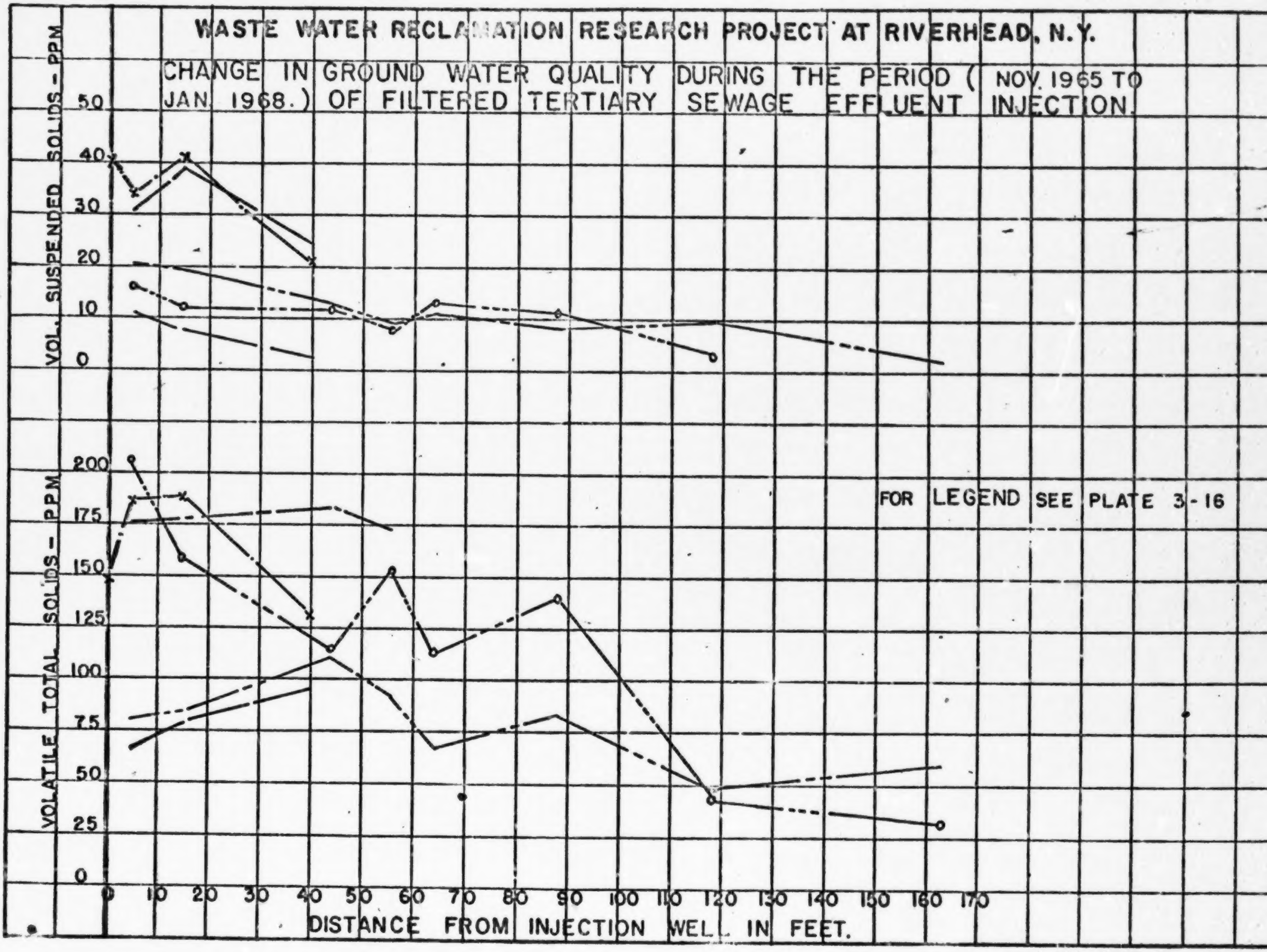
WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

CHANGE IN GROUND WATER QUALITY DURING THE PERIOD (NOV. 1965 TO JAN. 1968.) OF FILTERED TERTIARY SEWAGE EFFLUENT INJECTION.



FOR LEGEND SEE PLATE 3-16

PLATE 3-19



WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

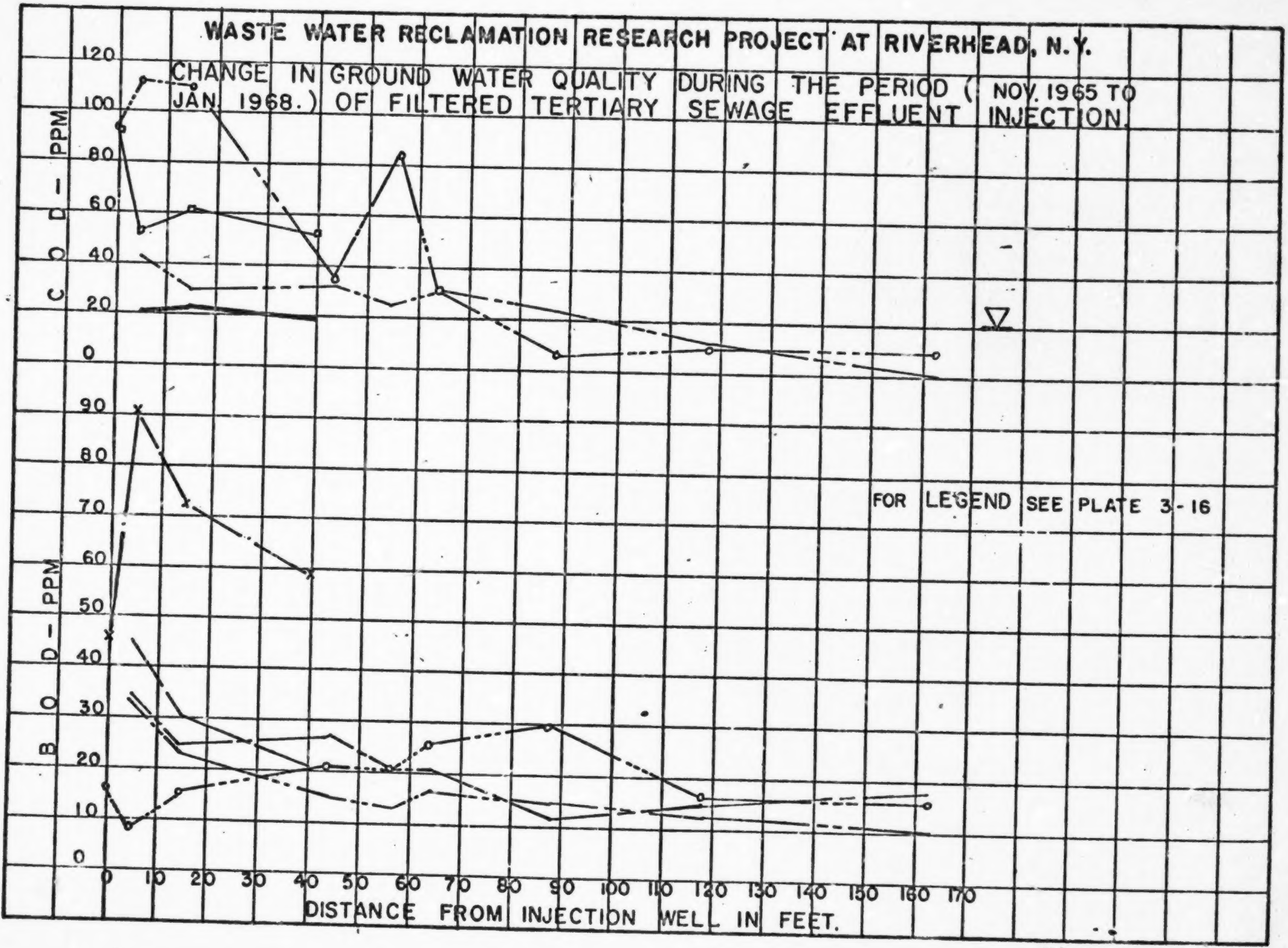
CHANGE IN GROUND WATER QUALITY DURING THE PERIOD (NOV. 1965 TO JAN. 1968.) OF FILTERED TERTIARY SEWAGE EFFLUENT INJECTION.

FOR LEGEND SEE PLATE 3-16

PLATE 3 – 20

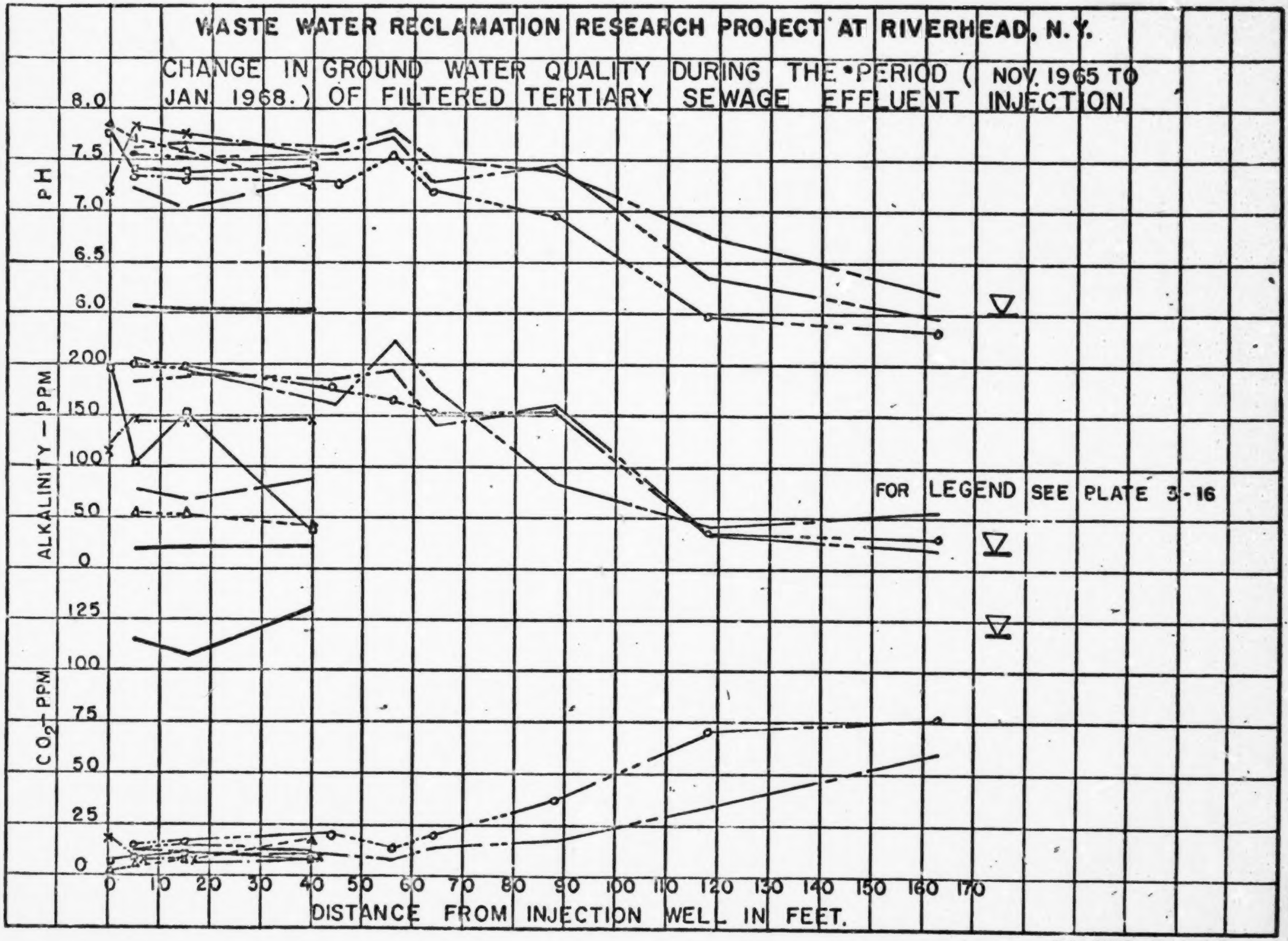
WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

CHANGE IN GROUND WATER QUALITY DURING THE PERIOD (NOV. 1965 TO JAN. 1968.) OF FILTERED TERTIARY SEWAGE EFFLUENT INJECTION.



FOR LEGEND SEE PLATE 3-16

PLATE 3-21



WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

CHANGE IN GROUND WATER QUALITY DURING THE PERIOD (NOV. 1965 TO JAN. 1968.) OF FILTERED TERTIARY SEWAGE EFFLUENT INJECTION.

PLATE 3 – 22

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

CHANGE IN GROUND WATER QUALITY DURING THE PERIOD (NOV. 1965 TO JAN. 1968.) OF FILTERED TERTIARY SEWAGE EFFLUENT INJECTION.

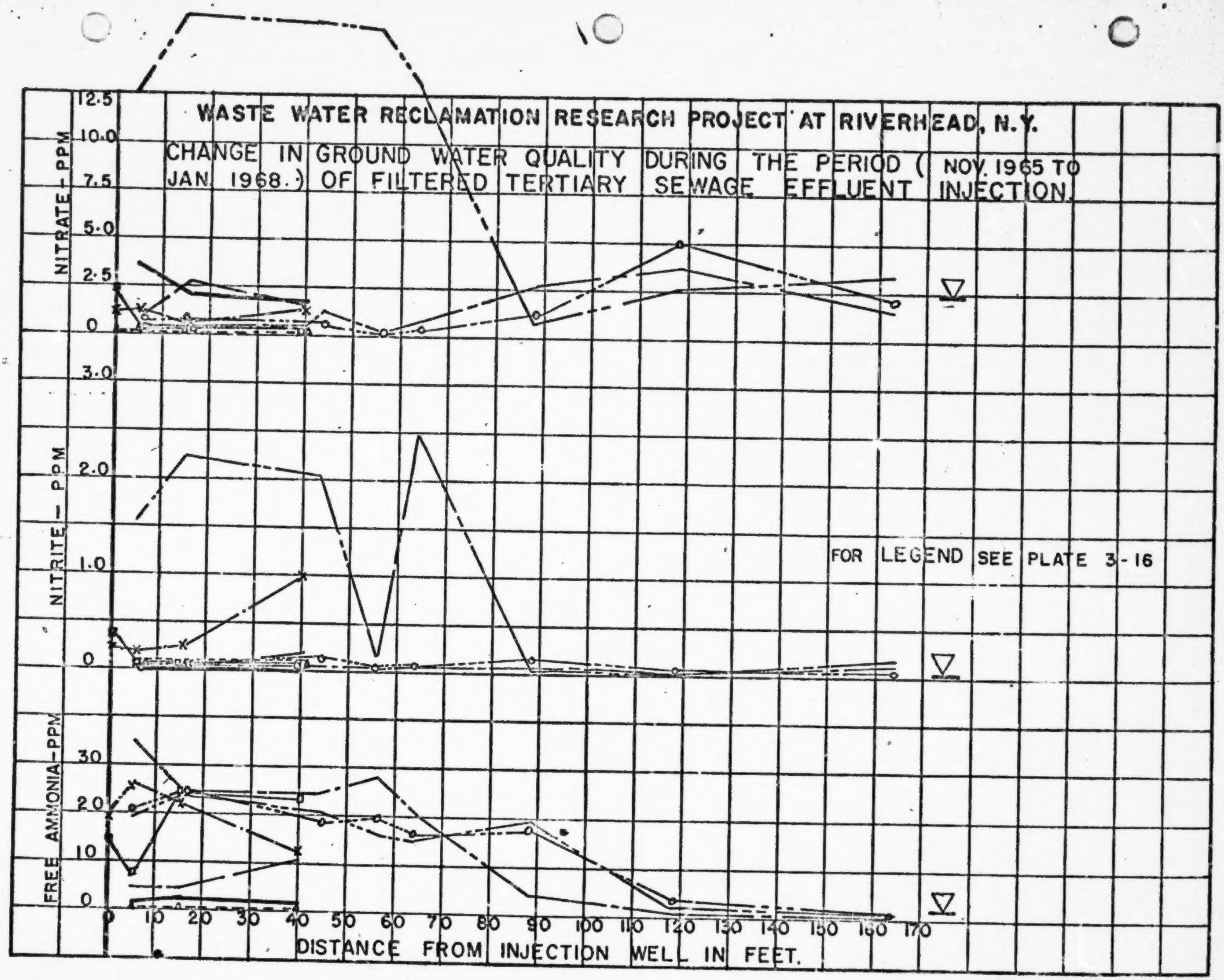


PLATE 3 - 23

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

CHANGE IN GROUND WATER QUALITY DURING THE PERIOD (NOV. 1965 TO JAN. 1968.) OF FILTERED TERTIARY SEWAGE EFFLUENT INJECTION.

NITROGEN CONTENT AS $NO_2^-N + NO_3^-N$

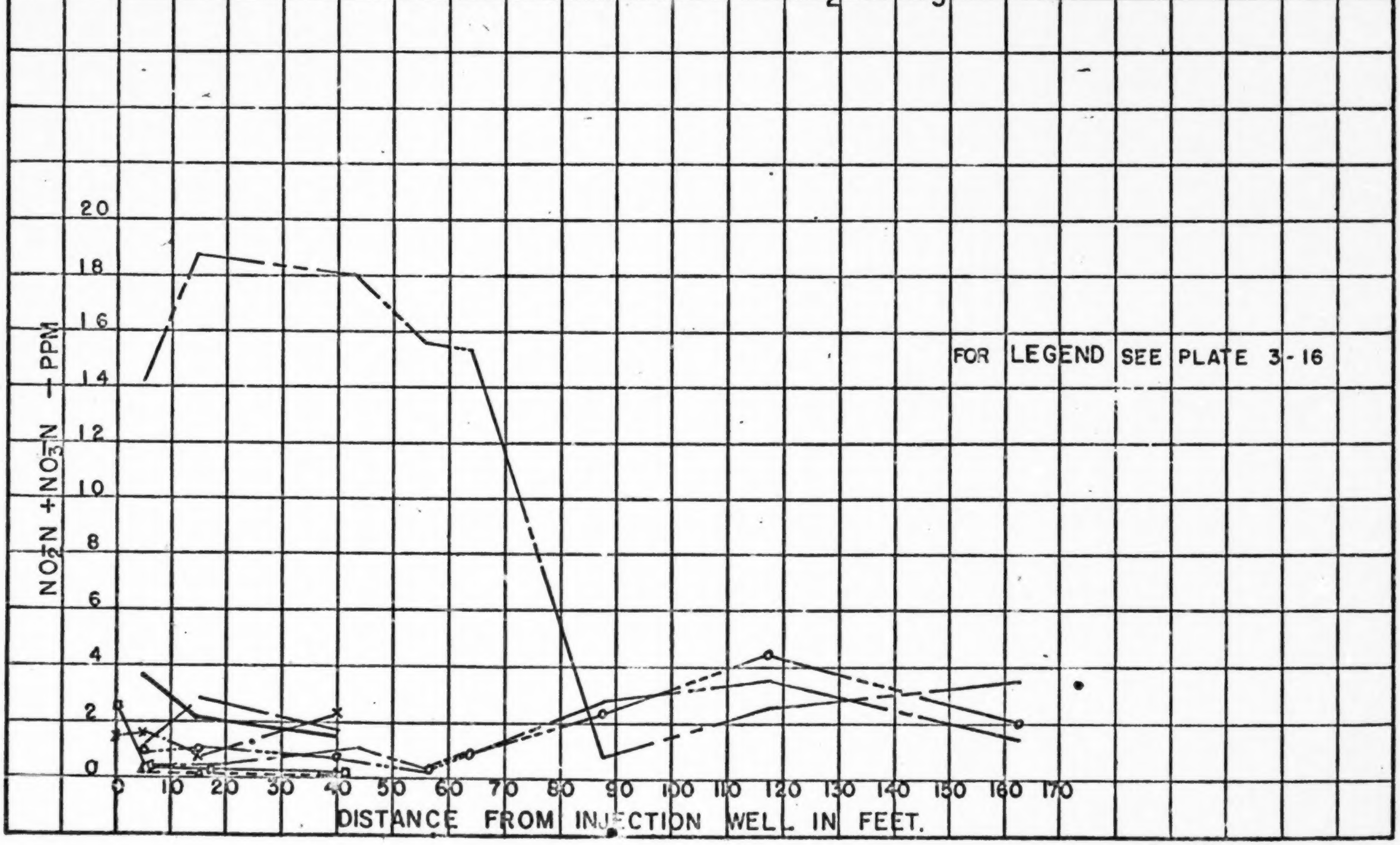


PLATE 3-24

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

CHANGE IN GROUND WATER QUALITY DURING THE PERIOD (NOV. 1965 TO JAN. 1968.) OF FILTERED TERTIARY SEWAGE EFFLUENT INJECTION.

NITROGEN CONTENT AS $NH_3^-N + NO_2^-N + NO_3^-N$ AND NH_3^-N

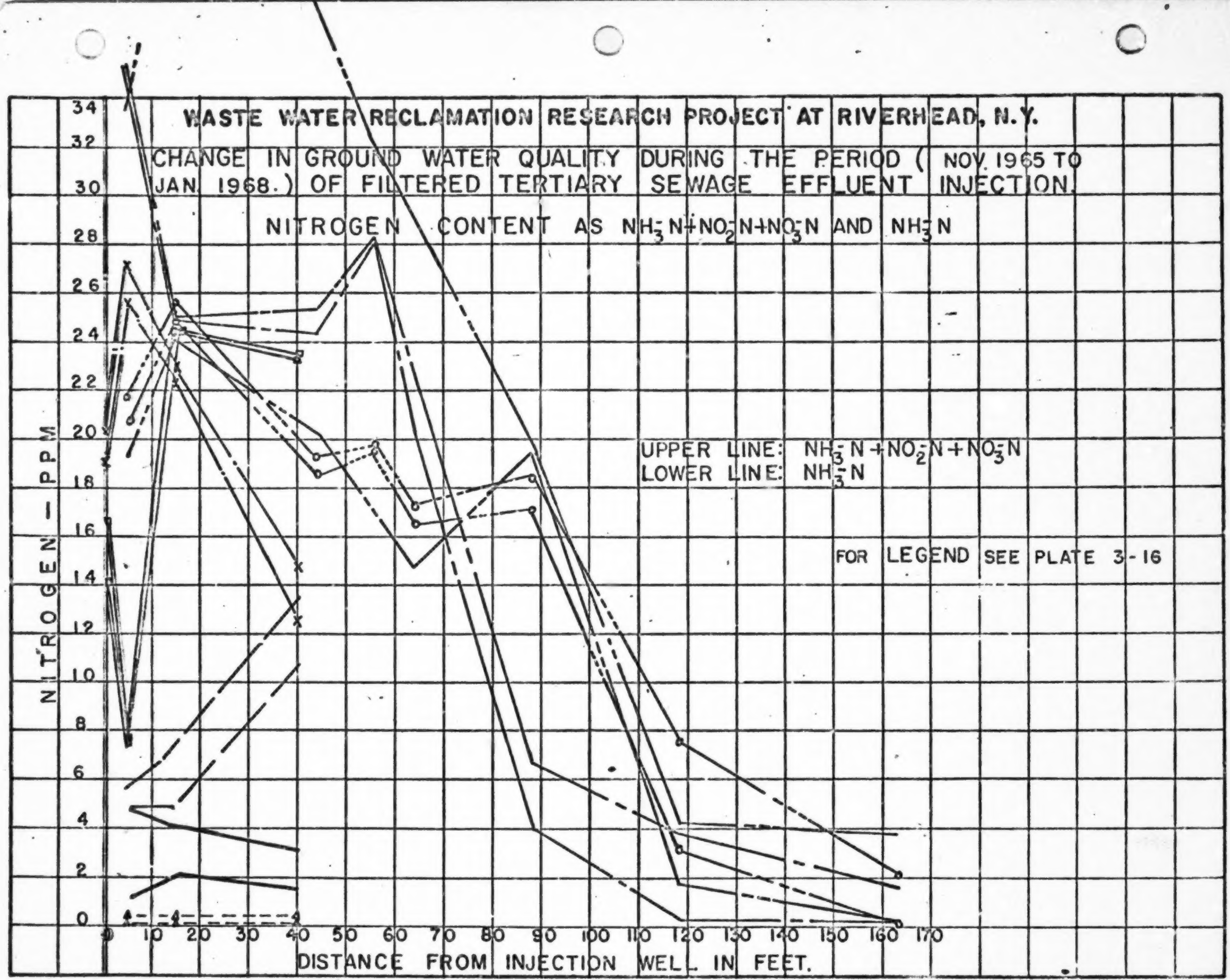


PLATE 3-25

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N .Y .

REMOVALS BY TRAVEL TROUGH AQUIFER SOIL DURING INJECTION OF FILTERED TERTIARY EFFLUENT (NOV. 1, 1966 TO DEC. 7, 1966)

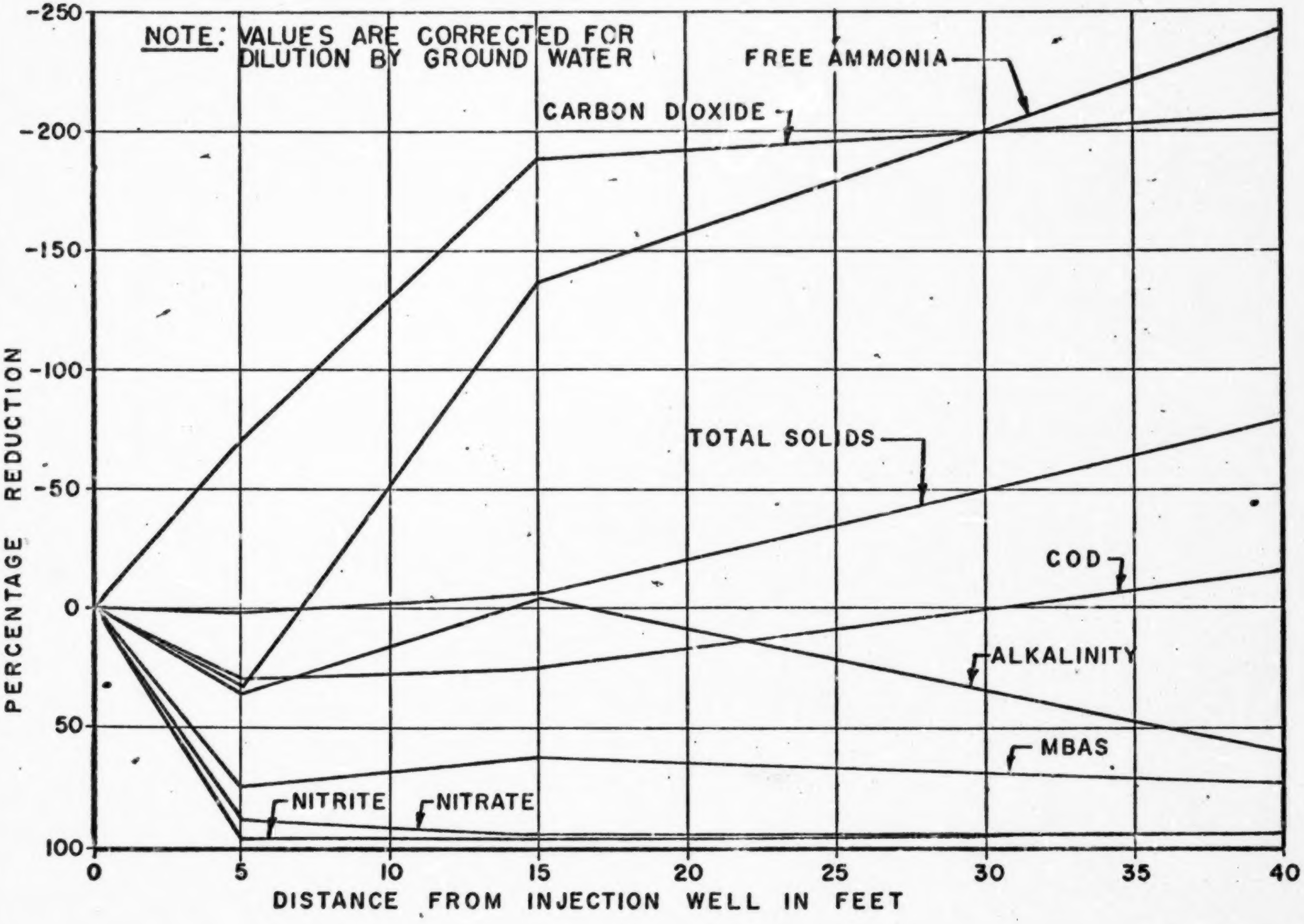


PLATE 3-26

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

REMOVALS BY TRAVEL THROUGH AQUIFER SOIL DURING INJECTION OF FILTERED TERTIARY EFFLUENT (JULY 19, 1967 TO AUG. 23, 1967)

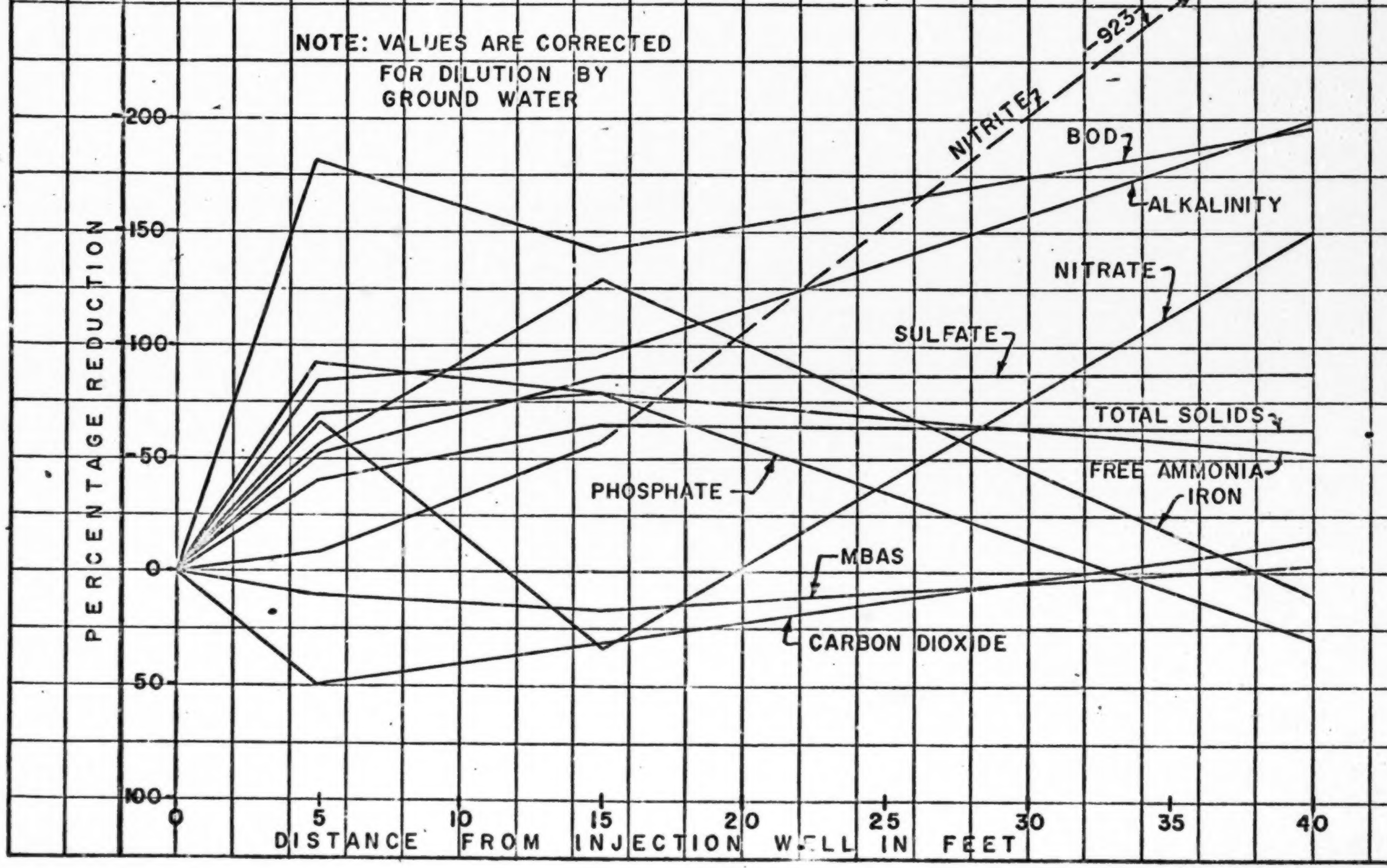


PLATE 3-27

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.
DECREASE IN INFILTRATION RATE THROUGH SIMULATOR SAMPLING TUBE AT CONSTANT HEAD AND TOTAL ORGANIC CARBON IN FILTERED SEWAGE EFFLUENT

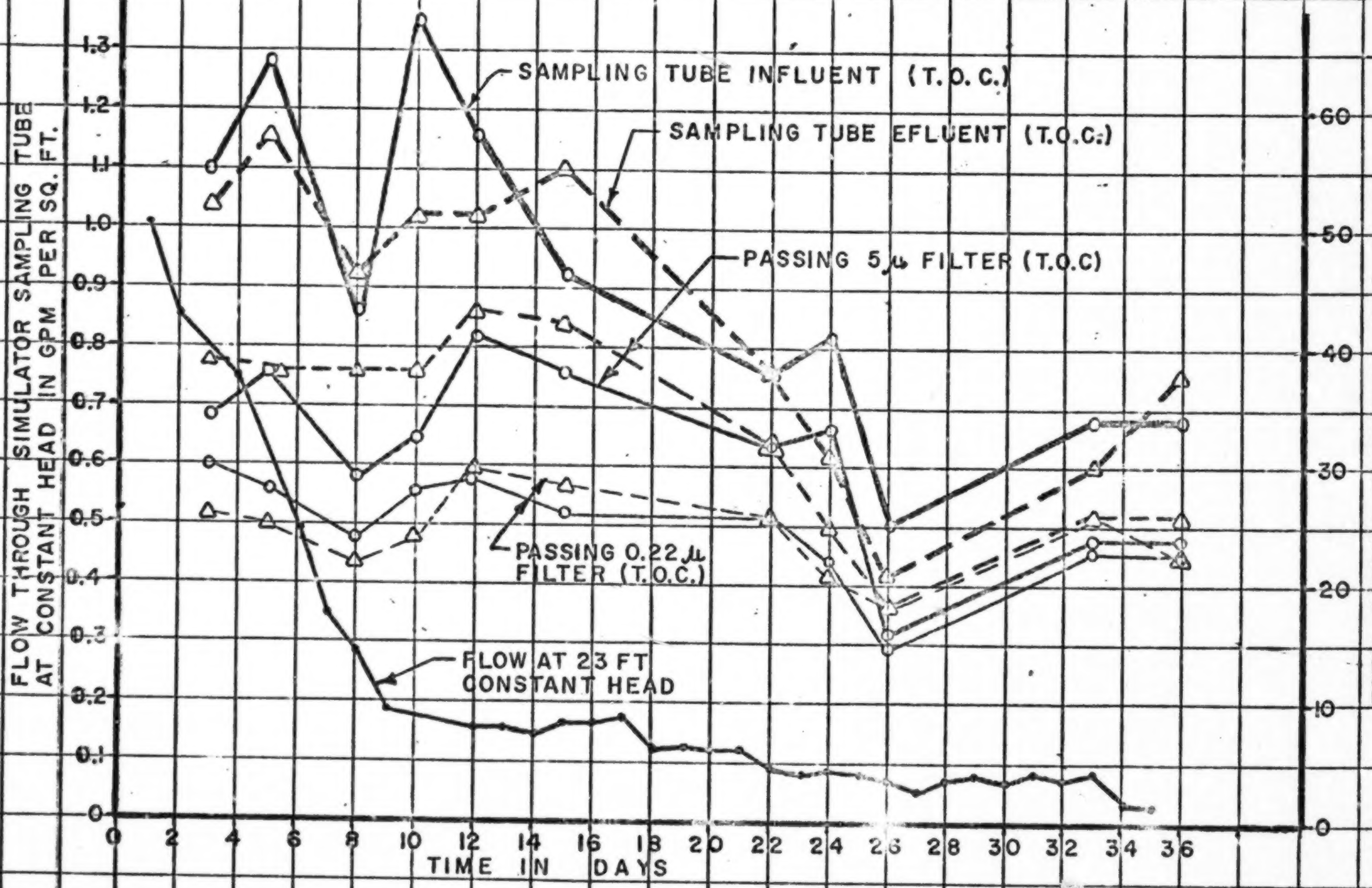
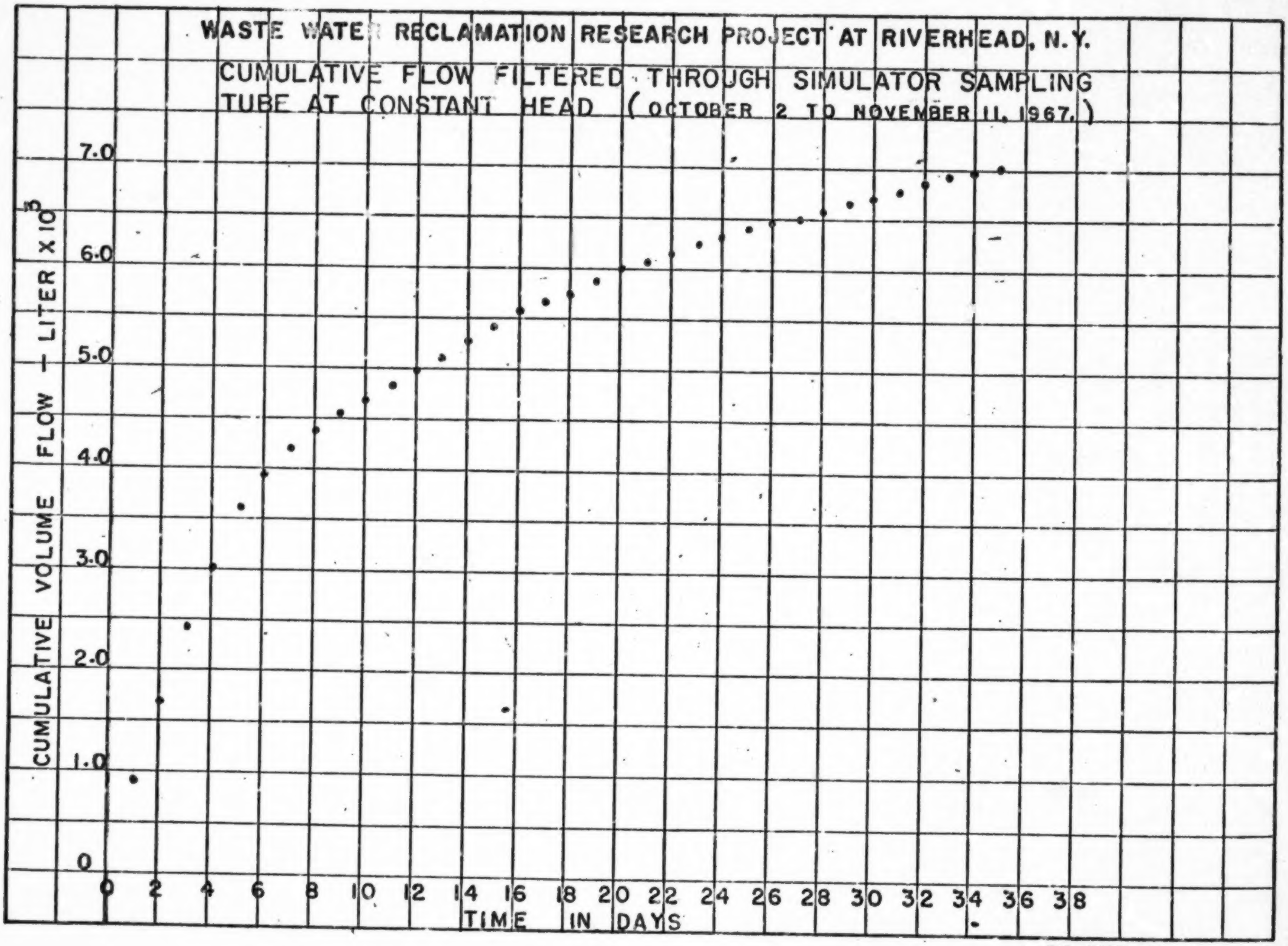


PLATE 3 - 28



WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

CUMULATIVE FLOW FILTERED THROUGH SIMULATOR SAMPLING TUBE AT CONSTANT HEAD (OCTOBER 2 TO NOVEMBER 11, 1967.)

PLATE 3-29

K&E SEMI-LOGARITHMIC 46 5493
KEUFFEL & ESSER CO

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

SIEVE ANALYSIS

SIMULATOR SAMPLING TUBE — CONSTANT HEAD TEST

AFTER 37 DAYS FILTERED SEWAGE INJECTION (OCT. 2 TO NOV. 7, 1967)

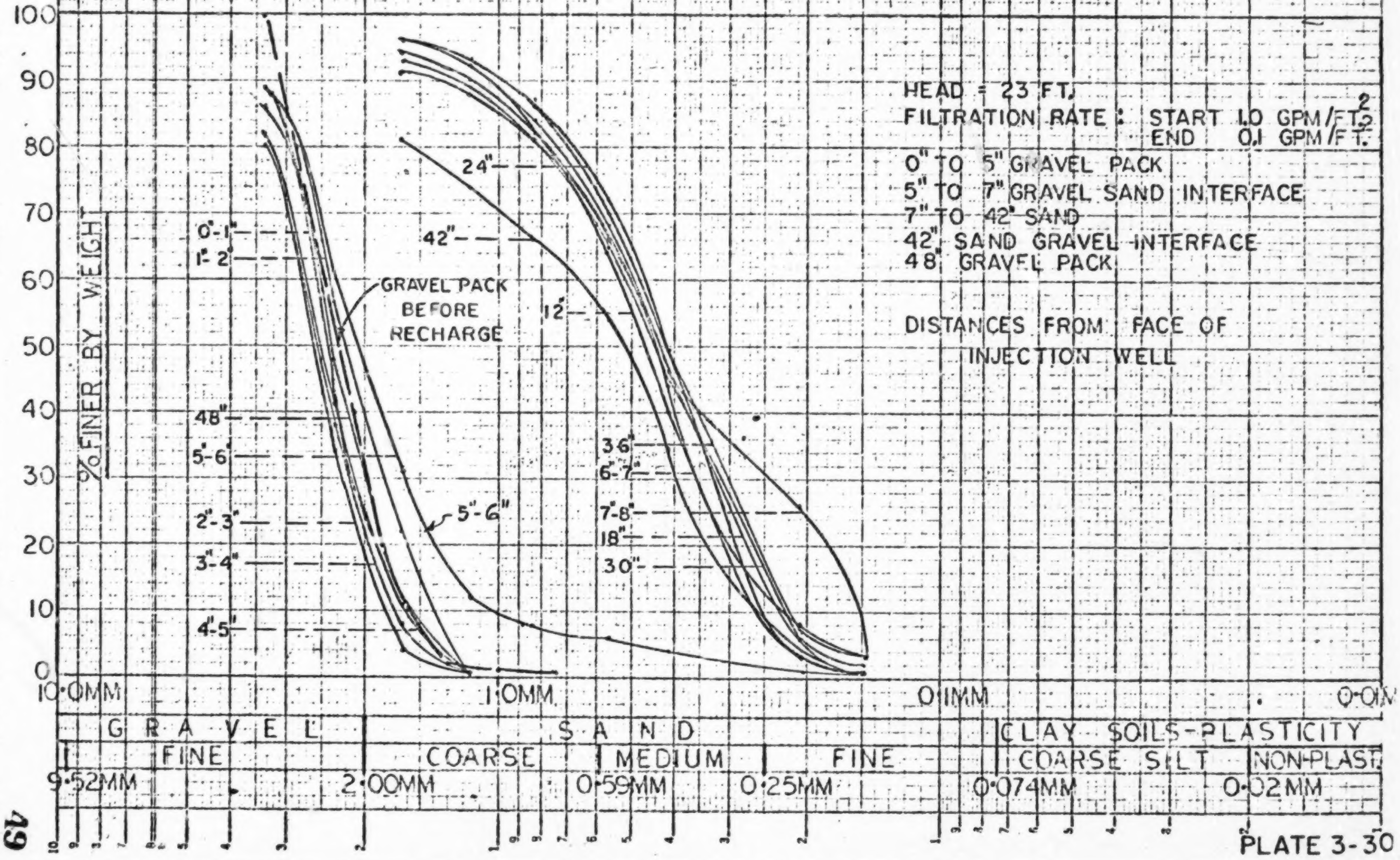


PLATE 3-30

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

ANALYSIS OF AQUIFER MATERIALS IN SIMULATOR SAMPLING TUBE AFTER 37 DAYS INJECTION OF FILTERED SEWAGE AT CONSTANT HEAD

OCTOBER 2, 1967 TO NOVEMBER 11, 1967

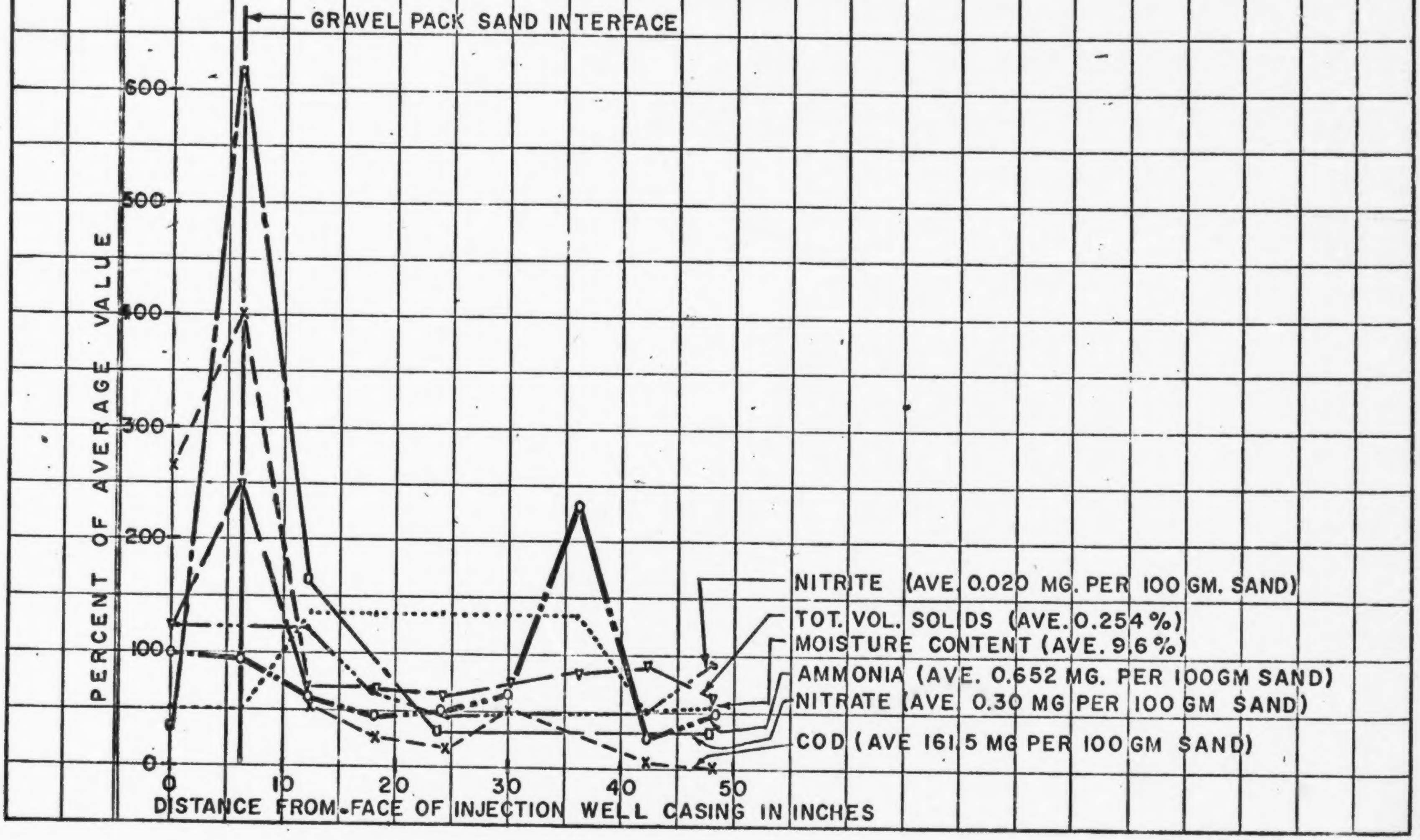


PLATE 3-31

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.
ANALYSIS OF AQUIFER MATERIALS IN SIMULATOR SAMPLING TUBE AFTER 37 DAYS INJECTION OF FILTERED SEWAGE AT CONSTANT HEAD

OCTOBER 2.1967 TO NOVEMBER 7.1967

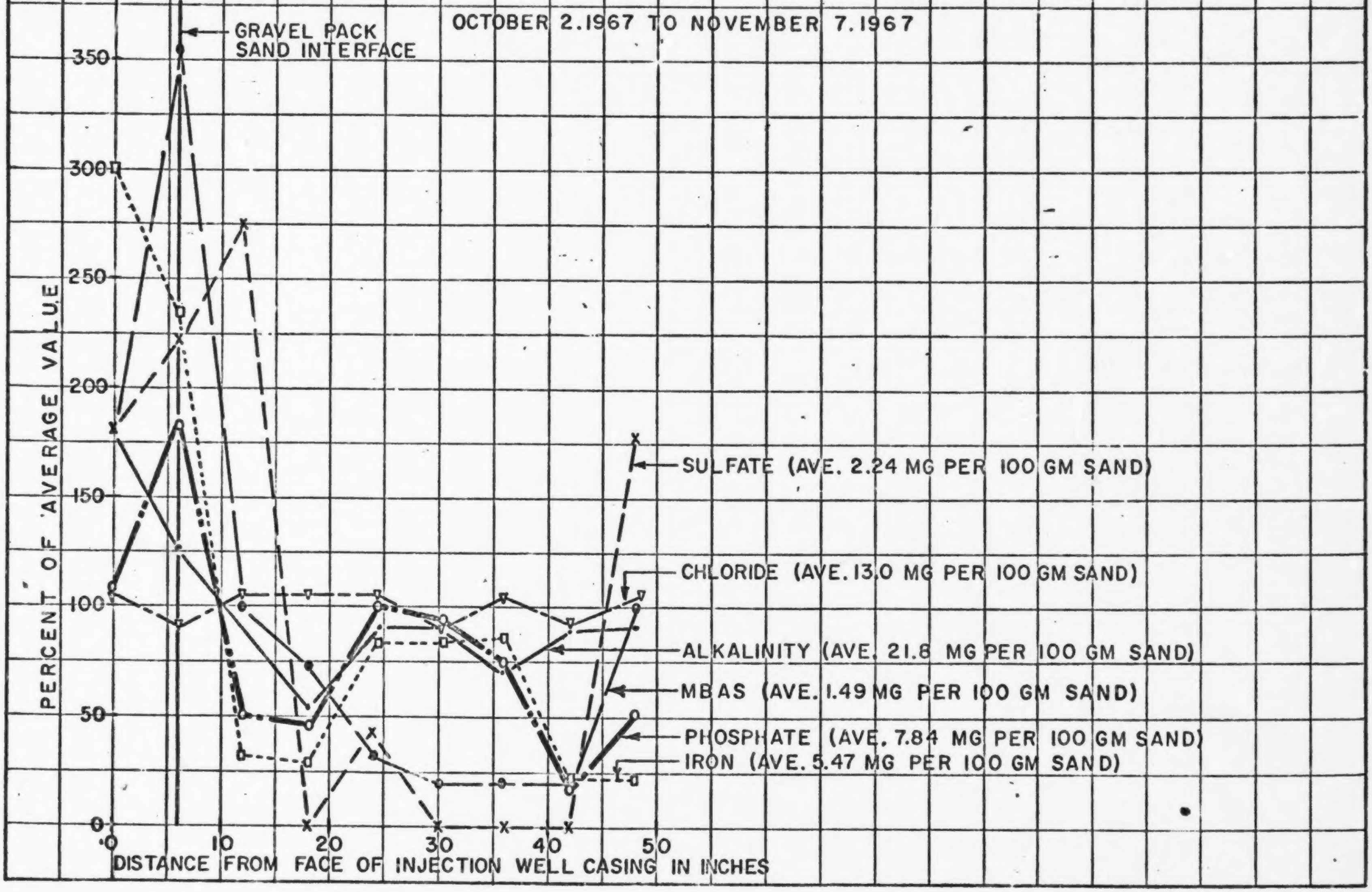


PLATE 3-32

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

NITROGEN CONTENT OF AQUIFER MATERIALS IN SIMULATOR SAMPLING TUBE AFTER FILTERED SEWAGE INJECTION AT CONSTANT HEAD

OCT. 2 TO NOV. 11, 1967

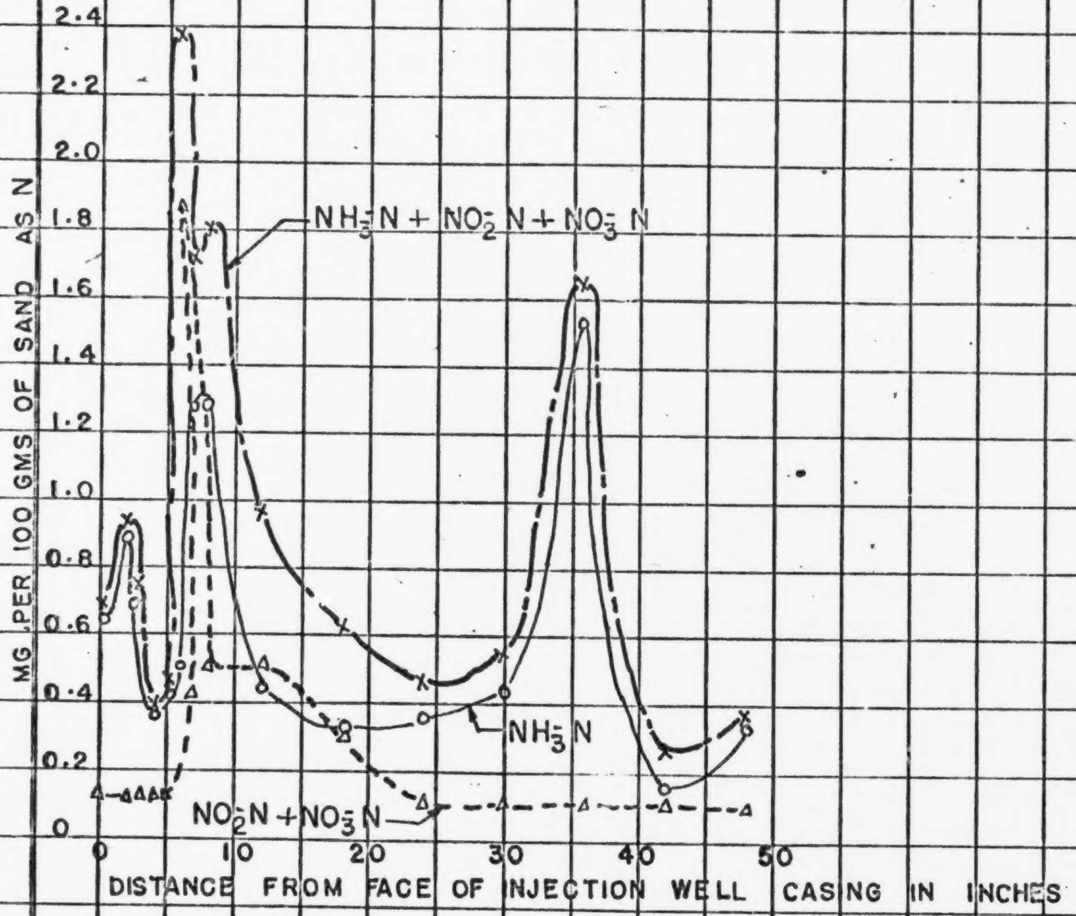


PLATE 3 – 33

WASTE WATER RECLAMATION RESEARCH PROJECT AT RIVERHEAD, N.Y.

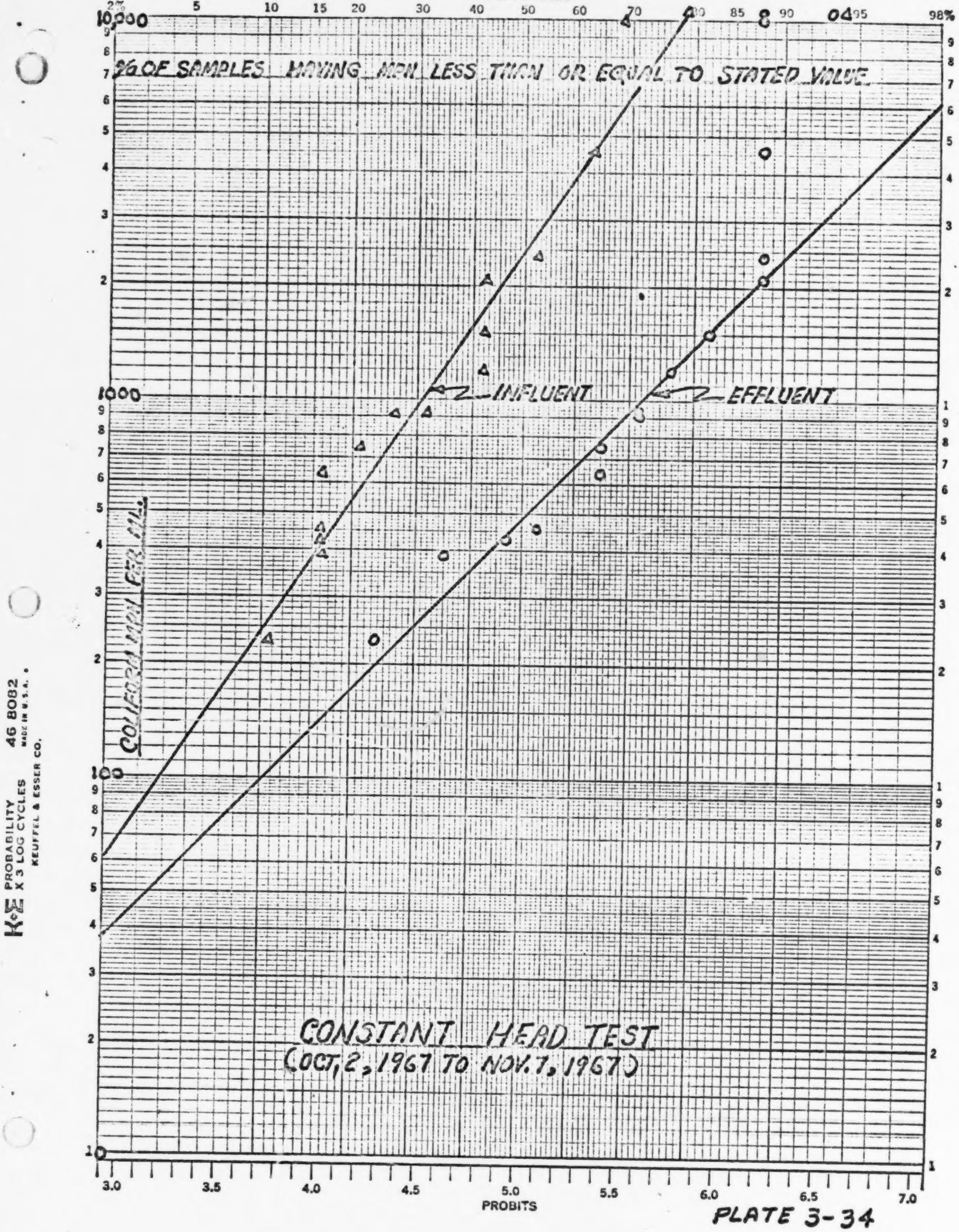
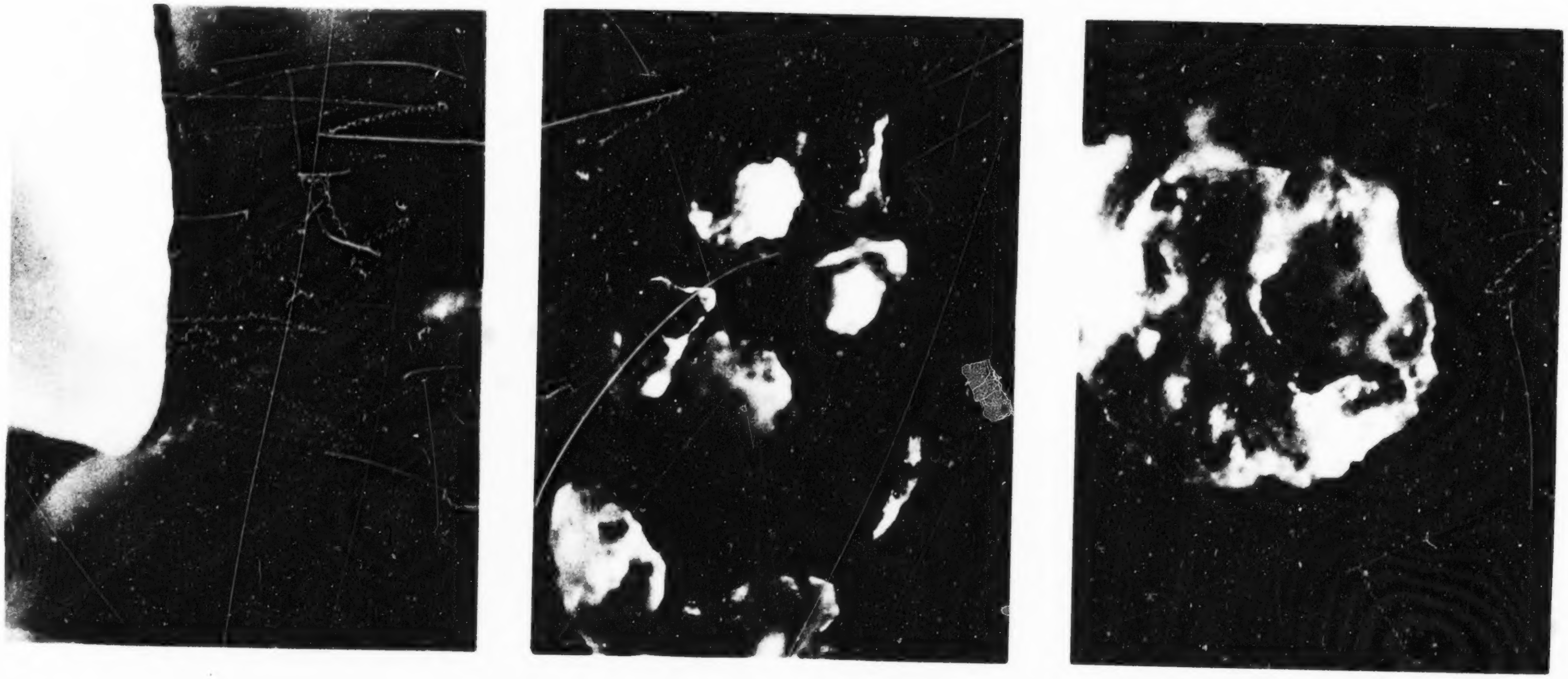


PLATE 3-34



GRAVEL (EXNER # 1)
AFTER ACID IMMERSION
(35 X - BRIGHT FIELD
INCIDENT LIGHT)

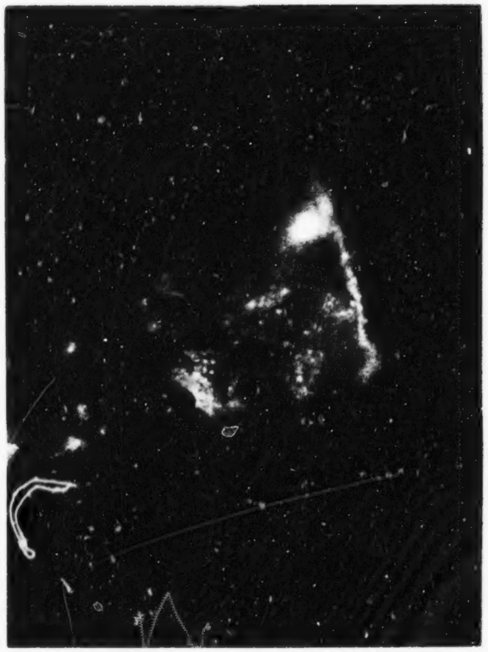
AQUIFER SAND
AFTER ACID IMMERSION
(35 X - BRIGHT FIELD
INCIDENT LIGHT)

AQUIFER SAND
AFTER INJECTION OF FILTERED SEWAGE
(35 X - BRIGHT FIELD,
INCIDENT LIGHT)

PLATE NO. 3-35: GRAVEL AND AQUIFER MATERIAL IN SIMULATOR SAMPLING TUBE SHOWING DEPOSITION OF FOREIGN SUBSTANCES AFTER INJECTION OF FILTERED SEWAGE.

GRAVEL PACK (EXNER # 1)
[illegible]" DISTANCE FROM INJECTION WELL
(52.5 X - DARK FIELD)

GRAVEL PACK (EXNER # 1)
2" DISTANCE FROM INJECTION WELL
(52.5 X - DARK FIELD)

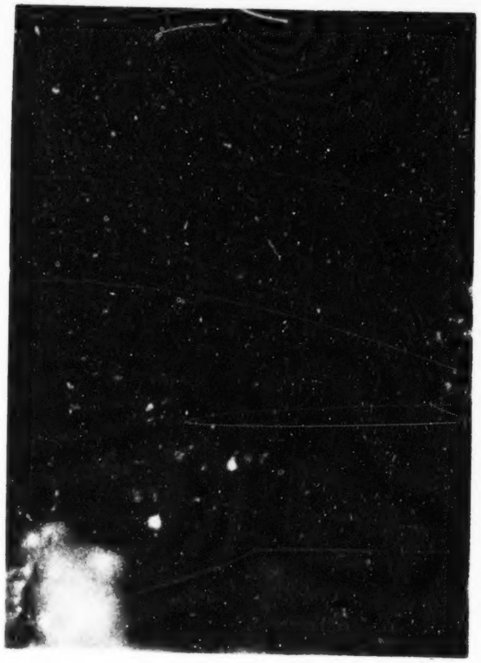


GRAVEL PACK (EXNER # 1)
5" DISTANCE FROM INJECTION WELL
(52.5 X - DARK FIELD)

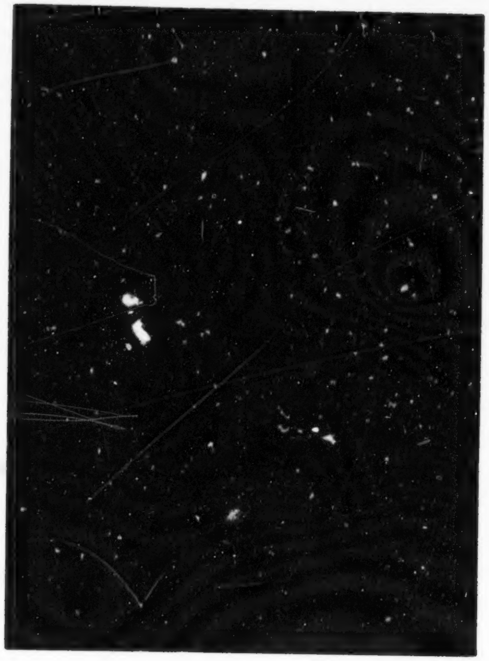
NOTE: 1 PPM FREE RESIDUAL CHLORINE WAS MAINTAINED DURING THE TEST

PLATE NO. 1-36: CONSTANT HEAD TEST. GRAVEL PACK IN SIMULATOR SAMPLING TUBE SHOWING DEPOSITION OF FOREIGN SUBSTANCES AT DIFFERENT DISTANCES

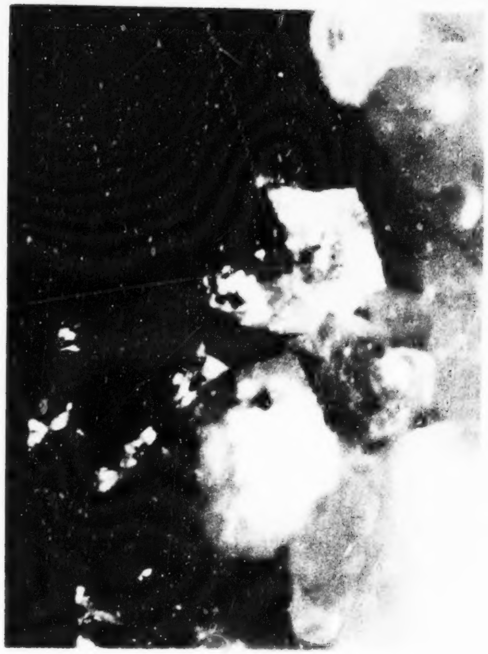
(OCTOBER 2 to NOVEMBER 7, 1967)



GRAVEL PACK (SHEET # 1)
[illegible] INJECTION WELL
([illegible] X - DARK FIELD)



GRAVEL PACK SAND SURFACE
6" FROM INJECTION WELL
(52.5 X - DARK FIELD)



A[illegible]
[illegible]
[illegible]

PLATE [illegible] CONSTANT HEAT TEST. GRAVEL PACK AND A[illegible] SATURATED [illegible]

[illegible]